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SUPPORT MECHANISM OF MATERIALS FLOW IN THE SPHERE OF PRODUCTION AT HILTI PLANT 04

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ABSTRACT

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This thesis was commissioned by Hilti AG for one of their largest production plants in Europe to support their production functions in the sphere of materials flow management.

Hilti AG is a large multinational manufacturing company that focuses on manufacturing, developing and marketing products for the professional users of the construction sector.

The purpose of this thesis was to research gathered information of production related operations at the plant and offer Hilti AG a solution to the improvement of the materials flow at the production site to increase the smoothness and efficiency of production.

Data was collected directly from the plant by conducting interviews with different department managers and working closely with the materials management team. Additional information was gathered from Hilti internal sources.

It was concluded that there are some ways Hilti could improve material flow and production operations at the plant by offering different solutions that would aid in their production efficiency according to already implemented LEAN management method at the plant.
The findings suggest, that by introducing the supportive functions mentioned in the proposal section of this thesis it is possible to enhance materials flow at the right time and increase the production outputs during the peak seasons.

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hilti, materials management, supply chain management, logistics, production management, operations management, inventory management, lean

CONTENTS

ABBREVIATIONS AND TERMS

FIFO	First in First out
JIT	Just in Time
LEAN	Manufacturing strategy
SAP	ERP System
APO	Internal ERP forecasting System
EOQ	Economic Order Quantity
Kanban	Scheduling system
Kaizen	Continuous improvement tool
Heijunka	Production leveling
MRO	Maintenance, repair and overhaul

1 INTRODUCTION

In increasingly complicated global supply chain operations, international companies are forced to adapt to many global trends that affect their business outcome. Increasing differentiation of customer patterns of demand, customer expectations of a quality and increasing financial risks that affect suppliers' networks are just one of the many arising trends that challenge business environments. Under these circumstances and new external pressures, businesses are forced to adapt and answer to these demands to achieve a successful operational result.

As long-term objectives such like customer servicing are becoming more important than ever, Hilti is keeping their customers at the top priority by ensuring that the right demand is met precisely. This is done by an extensive and wide range of supply chain networking and careful and thorough production planning processes.
Production operations are thus one of the most important target areas for Hilti, not only to create long-lasting tools, but also to produce in a smart way, that is financially feasible way while thinking of the environment as well.

This thesis focuses on the production operations by including important concepts such as inventory operations as well as procurement functions in the sphere of materials management at the Hilti production facility in Thüringen.
Production is one of the most essential parts of the manufacturing company and many factors must be taken into the consideration to ensure the smoothness of operations. It is also one of the most difficult operations to manage due to constant fluctuations of demand, materials availability and issues in machining and workforce.
This topic explains different production related theories and possible improvements of flow material management at the plant, in order to make production more efficient.

1.1.1 Thesis objective

The objective of this thesis is to introduce a tool through examination of production processes, that support the production functions and activities at the Hilti plant site. The formulation of the problem is therefore: "Is it possible to create a system, that supports the production function in the production operations to ensure the smoothness of production operations by offering a consistent tool, that can track the material flow in the production related processes".

1.1.2 Theoretical background

Only the related theories to the materials management will be presented. There are important concepts that go beyond the production and focuses of material flow. This is important to know, what materials are, what is done to them and how are they handled.

1.1.3 Data obtaining methods

Exploratory research method is used in this thesis. First, all the data is aggregated and then distilled according to the needs of the topic. Thus, only selected data is added, and more data is obtained for further information.
Primary data is acquired from internal and external sources. Hilti's internal news channels are used. Such data is intranet and magazines meant for the stakeholders of the company. Secondary data is obtained through interviews with different managers, coaches as well as workforce on a shop floor level.

1.1.4 Thesis structure

Second chapter of this thesis introduces to production management operations. It explains common production theories and methods used in manufacturing companies. This chapter includes scheduling processes, when it is good to start producing, what quantities of productions are required, what constrains can there be and how the demand affect the overall production operations in a big company. In addition, it gives insights to how production operations are used in Hilti plant and what are the current issues that are related to this topic.

Third chapter explains the existence of inventory systems and typical inventory types that exist in manufacturing companies. Inventory classification systems and optimization of inventories by setting re-ordering points of materials as well as safety stocks are also explained. As these systems are existing to prevent stockouts and ensure smoothness of production operations as well as to have optimal amount raw materials, this chapter is linked to LEAN management systems.

Fourth chapter focuses on LEAN management systems. It systematically explains different functions of the LEAN method and their importance for any global manufacturing company. This section also includes the explanation of the reason why many other companies adapt this production system.

Fifth chapter explains ERP functions and their importance as well as how this software support mass amount of data in a big company.

Sixth Chapter includes key findings of the operations which were obtained at the plant.

In the seventh chapter various proposals to Hilti are made. This section also includes the concluded part of this thesis.

1.1.5 Research method

The nature of the research was exploratory. It was conducted by actively gathering all the data and supported by extensive independent research on the issues that had an impact on the production processes.
Data was gathered by participating in numerous projects that are related to the production topic, meetings with materials managers that are responsible of the production related operations, procurement managers, sourcing managers, lean manager, inventory coach and assembly line coach.
Data gathering was conducted by obtaining information from a materials manager.

1.2 Hilti AG

Hilti is an international family owned company that specializes in manufacturing tools and software for the construction and energy sectors. The core business of Hilti lies in providing right tools for the right purpose with a strong focus of servicing their customers and providing support that meets their customers' needs.
Today the company has operations in more than 120 countries worldwide and employs approximately 27000 employees. (Hilti, 2018). Hilti continues its strong growth on a global scale by continuing to provide tools, spare parts, software for construction sector with a strong focus on customer servicing of all customers around the world. (Hilti, n.d).

Hilti was founded in Schaan, Liechtenstein by Eugen Hilti and Martin Hilti in 1941. The business started its business activity by opening a mechanical workshop. At that time, main business focus was the production of automotive parts that were supplied to other companies. Their business focus changed and began to lean towards production of construction tools and spare parts for the construction sector. By the time of 1957, Hilti was already actively present in 30 different countries. (Hilti, 2018.)

1.3 Hilti Plant in Thüringen

Thüringen production plant 04 is located in Vorarlberg region in Austria. It is currently the biggest regional and biggest Hilti production plant in Austria. Production focuses on manufacturing drilling, saw and fastening tools. (Hilti, 2018.)

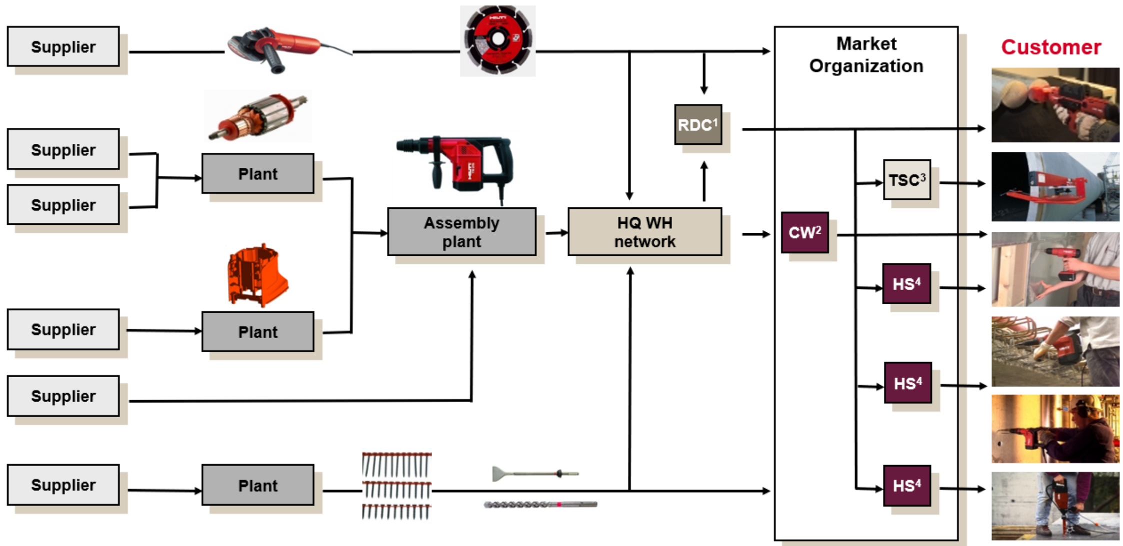
Picture 1. Drilling tools, diamond tools and fastening tools which are produced at the Hilti plant 04 (Hilti, 2018).

The plant consists of 3 segments: production line, assembly line and the inventory.
Spare parts and tool components are manufactured in the production line after which they are either sent further along the supply chain through the assembly line or are stored in inventory. (Hilti, 2018.)
Entire plant 04 of Hilti operates almost fully with the LEAN principle that enables the plant to run production and assembly as well as inventory related operations as cost efficiently and efficiently as possible. Hilti continues to increase LEAN method in their plant by focusing on waste elimination and increasing its focus on its supplier chain. (Hilti 2018.)

Picture 2. Hilti Plant 04 in Thüringen, Austria (Hilti, n.d)

1.4 Supply chain network of Hilti

Hilti has extensive supply chain around the world. Raw materials are obtained from suppliers and components are produced in different factories. After the production process, parts are assembled and sent either directly to warehouse units or delivered directly to market organizations. Customers receive the products directly from the market organizations that are strategically located in each country. (Hilti, 2018.)



Picture 3. Material flow from suppliers and plants to the end customer. (Hilti, 2018).

2 PRODUCTION

Production is a process in which inputs are transformed to outputs. In an industrial organization this means an activity in which the flow of components that enter the process stream as inputs are transformed within the process and then exit the stream as outputs which accumulated added value through the entire process.

There are many different inputs depending on the organization. In the manufacturing organizations, typical inputs are workforce, machines, materials or money and outputs can be either desirable or undesirable. Desirable outputs are outputs that were expected from the planned production spectrum. Undesirable outputs are typically waste or defects that were produced as a by-product. Undesirable outputs are never intended by-production.

Improvements or results of the production process are achieved by a feedback function, which report the information from the beginning and the end of the process chain. These reports may be satisfactory or unsatisfactory. (Aswathappa & Shridhara Bhat, 1.)

There are some minor differences between distinct definitions such as manufacturing and production. Both terms mean the same, however manufacturing is often understood as a process of producing tangible goods, whereas production can mean both production of tangible goods or intangible goods. (Aswathappa et.al, 1.)

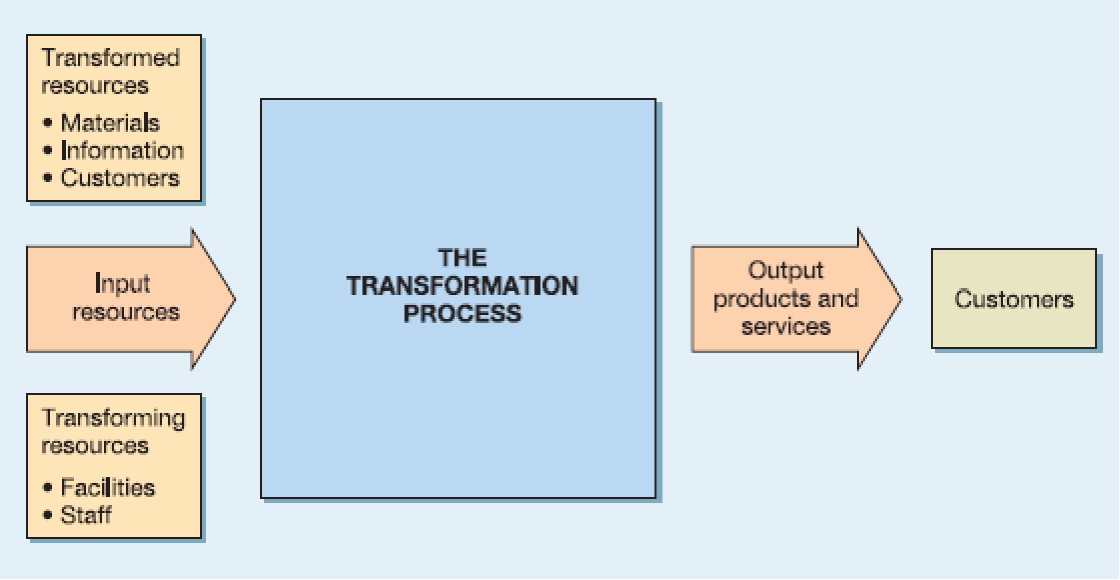


Figure 1. Production inputs and outputs (Slack, Chambers, Johnston, 2010, 11)

2.1 Types of production

According to Bhasin (Bhasin, 2018), there are 4 most commonly used methods of production:

- Job production
- Batch production
- Mass production
- Process production

Job production is when companies manufacture a specific tangible or intangible product. The production process in this segment is highly tailored to meet the customers exact needs. Job production is quite common at the restaurants when customers make a specific order and the product is being developed to satisfy the customers demand. These products are highly individual in nature and due to that, they tend to be expensive as compared to batch or mass types of production. (Bhasin, 2018.)

In batch type production the production is based on orders or forecasted amount. In this type of production, the organization is aware on the amounts goods that need to be manufactured and therefore large quantities of the same type of products are produced in one batch. The production focus is in one batch a time, meaning that no other products than assigned at a time are produced until the batch is completed. Once the production of a batch is complete, a new batch production may be assigned for the next production operation.
Sometimes an inventory system is needed in where the goods can be temporarily stored and inventories for raw materials and work-in-progress components are required. (Bhasin, 2018.)

Mass production is a continuous flow of components or subassemblies that pass from one stage to another. The product is moving from one stage to another upon completion of the task at a given phase. The production has a clear layout of processes and functions at different stages. Production is highly standardized and there is no deviation between produced products. (Bhasin, 2018.)

Just like mass production, process production is a continuous production. The difference between mass production and process production is the mechanical involvement. In mass production machines and workforce work closely together, whereas in process production there is no requirement of workforce.

Common industries that utilize process production are for instance brewing industries or petrochemical industries. (Bhasin 2018.)

According to Bhasin, (Bhasin, 2018), production options depend on the market demand, the supply of the raw materials and the product.

Based on these factors it is possible to select the right production method to answer the existing demand by matching the production outputs with the demand. Long-term investments of machinery and workforce also affect the choice of production method required.

2.2 Production Plan

There are overall three different time horizons that a company may use for the planning of the production (Aswathappa & Shridhara Bhat 2009, 235).

- Long-Term plan
- Intermediate plan
- Short-Range plan

Long-Term plans are strategical, and they are developed by the highest hierarchy of the company. Executives work on long-horizon plans to develop a long-time plan, which includes the strategical goals of the company. Such plans consist of production, facilities, market knowledge, equipment for production to create the demand to have enough revenue of cash flow to the company. (Aswathappa et al. 2009, 235.)

The inputs to long-term plans are capacity information, demands based on forecast amount and availability of capital. The outputs can be for example plant location, machinery plans, capacities of the plant, layouts. (Aswathappa et al. 2009, 236.)

Since long-range plan focuses on a long-time perspective, the planned period can be up to 5 years. (Markgraf, 2018).

Intermediate-horizon plans are typically the responsibility of mid-level managers. Specifically, operations managers are responsible of creating and maintaining these plans.

The focus of these plans is the aggregated products and parts meant for production activities. The plans include utilization of machining operations, workforce management, materials management and facility-oriented operations.
The period of intermediate-horizon plan is 6 to 18 months but can be longer or shorter.
Short-range plans are operational, and they focus on short-term activities within the production, which include scheduling of products that need to be produced with a timeline of a week to a month.
Management focuses on master production scheduling, material requirements planning as well as capacity requirements planning. (Aswathappa et al. 2009, 236.)

2.3 Aggregate Plan

Aggregated plan is an intermediate plan which concerns the production scheduling and determines the capacities based on business forecasts. It differs from long-term planning by focusing on achievements of current capacities of workforce and raw material availability. The typical aggregate plan horizon is from 3 to 18 months. (Papantos, nd.)

2.3.1 Material Requirements Planning

A manufacturing company may hold different types of inventories meant for the production processes. These inventories are consisting of raw materials, subassemblies and finished products. The demand for raw materials and other subassembly parts that are outputs to a finished good are said to be dependent because the product is directly depending on all of those required inputs to have a finished product. A finished product has an independent demand because the finished product is already a product that is ready and thus not an input to any further processes. (Stevenson 2015, 495.)

Materials requirements planning (MRP) is a tool that is used to see what materials are required at what time to produce a finished good. Inputs to the materials requirements planning are (BOM) bills of materials and (MPS) master production schedule. (Stevenson. 2015, 496.)

Having a clear requirement of materials required and a schedule when to product, manufacturers create a specific production plans by using an MRP tool. Because of the clean structure of an MRP, many companies adapted the Enterprise Resource Planning (ERP) software that tracks the required amount of materials based on customers' orders that are showed up in the ERP system.

The positive aspect of the MRP is its simplicity of use and easy understanding. Negative point is that it must be accurate. All customer orders must be tracked and a clear on hand through BOM file are required. If an MRP is false, then there is a risk that the production is also false. (Heizer, Render & Munson 2017, 567.)

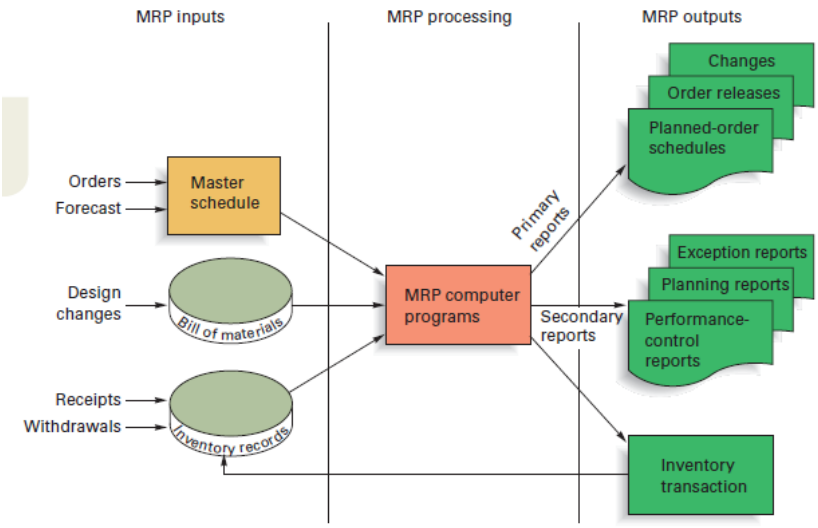


Figure 2. Inputs and outputs of MRP (Stevenson, 2015, 496)

2.3.2 Master Production Schedule (MPS)

Master Production Schedule is a schedule that tells what products should be produced and when products should be produced based on information of aggregated plan. MPS satisfied the demand by disaggregating the aggregated plan to give a structure of products that are required to be produced to meet the demand at a given point. (Heizer et al. 2017, 567.)

Aggregate Plan
(Shows the total quantity of amplifiers)

Months	January				February			
	1,500				1,200			

Master Production Schedule
(Shows the specific type and quantity of amplifier to be produced)

Weeks	1	2	3	4	5	6	7	8
240-watt amplifier	100		100		100		100	
150-watt amplifier		500		500		450		450
75-watt amplifier			300				100	

Figure 3. Master Production Schedule (Heizer, Render, Munson 2017, 567)

2.3.3 Lead times for components

Once production information in terms of what products needed to be manufactured information is available, the next step is to find out the exact lead times of materials required for the production. Lead time is the time between the procurement and the receive time between production orders. This information is essential, and tells the exact time, when the products should be ordered and thus available for the production to smoothen out the production processes to satisfy the demand. This information is especially important in Just-in-Time concept. By knowing exact lead times, it is possible to procure items at the exact needed time, to produce exact required parts and requirements. (Heizer, et al. 2017, 570.)

2.3.4 Bills of materials (BOM)

Bills of material is a file, that shows requirement of inputs such as components or raw materials to produce a product. (Heizer et al. 2017, 568.)
For example, to have a Product A, a part B is required and to have a part B requirement could be C and D. Bills of Materials list shows the exact number of components or raw materials needed to have a part (Heizer et al. 2017, 568).

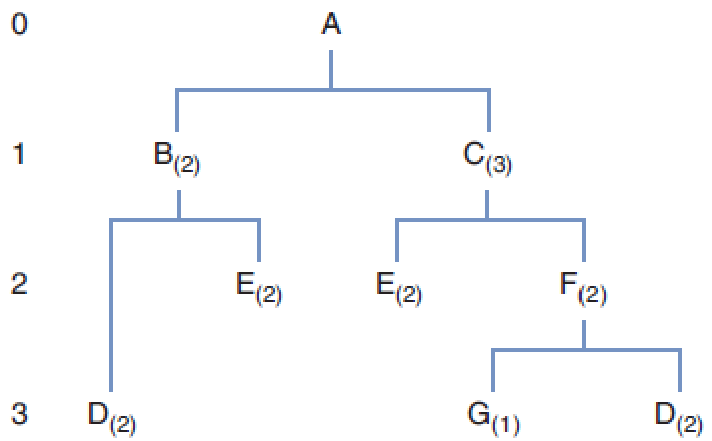


Figure 4. Bills of Material file explodes a product by showing different requirements of components (Heizer, Render, Munson 2017, 569)

2.4 Capacity planning

Before having a capacity plan, a company must first find out the overall demand in the market whether there is a need for the products that are being produced. Since the demand is usually never constant and it tends to fluctuate, it is also important to find out when the demand is at its peak and when it is at its minimum. This data can then be used to calculate the capacity rates, the machines or workforce is able to produce at a given time.

Capacity planning is important part of the production because it tells the maximum capacity and shows certain restrains in the production. Through capacity plan it is possible to calculate the maximum production rate. It is important to notice, that capacity planning is connected to the production rate and not the quantity. (Arnold, Chapman, Clive, 2008, 125.)

There are two kind of capacities that should be considered in the planning phase. The available capacity and maximal capacity.

Available capacity is the capacity in which inputs could still be added until capacity reaches a maximum capacity. When production reaches its maximal capacity, outputs are equal to inputs but less than inputs if inputs continue to increase. (Arnold et al. 2008, 126.)

2.4.1 Constrains

Constraints are insufficienscies within the processes that slow down the entire process chain in one point. In production operations this can typically be machines which workload reached maximum capacities. Higher inputs and low outputs are a sign of such processes. (Heizer, Render & Munson 2017, 314.)

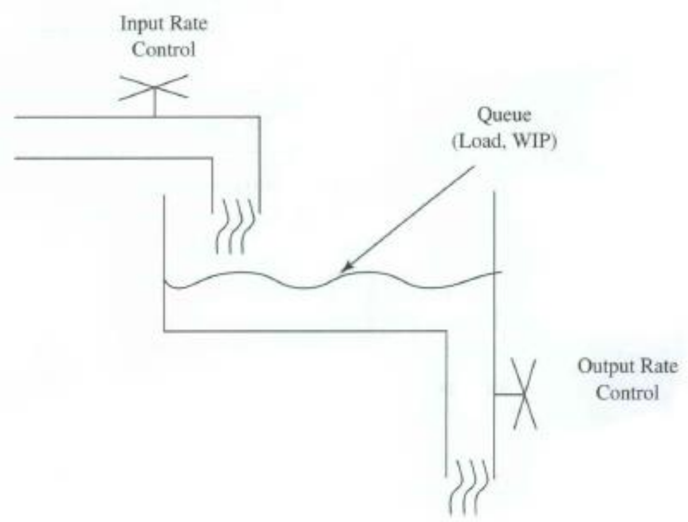


Figure 5. Production material flow constrains (Chapman, Arnold, Gatewood & Clive 2017, 163)

In one of the production sites in the Plant 04 there are overall 4 machines that work as a connection to one another. These machines are 1, 2, 3 and 4.
Both 1 and 2 produce parts for 3 and 4. Machines 3 and 4 then produces an output to a Furnace. The flow of parts then continues to Quality inspection, where the parts are inspected and from there moved externally to other business units or stored to a warehouse at the plant.

The bottleneck machines are 3 and 4 because the production on both machines takes the longest. Both machines are operated in 3 shifts and are running without a break.
Although Furnace may seem like it is a bottleneck, it has a faster processing time and its outputs are greater than inputs.

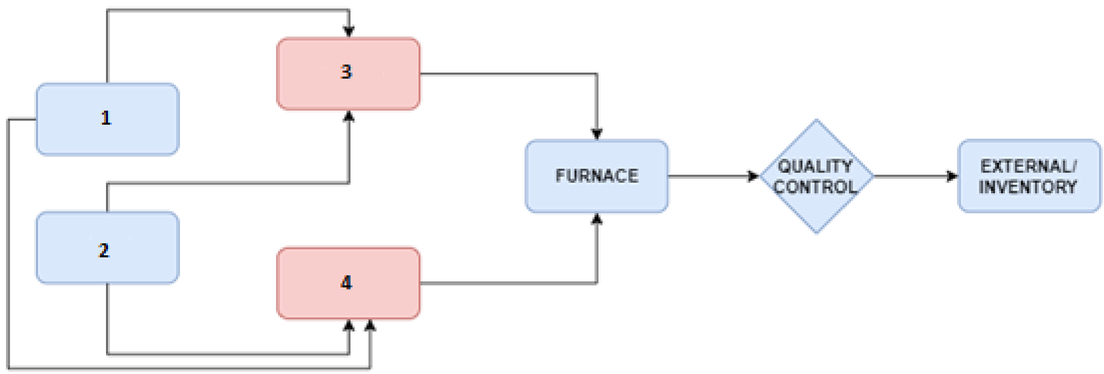


Figure 6. Materials flow in the production site

2.5 Manufacturing Strategies

Highly competitive companies that are market-oriented are focused on the customer. This means that such companies make sure that there is always just about right supply of their products that are met with customers' expectations. (Chapman, Arnold, Gatewood & Clive 2017, 15).

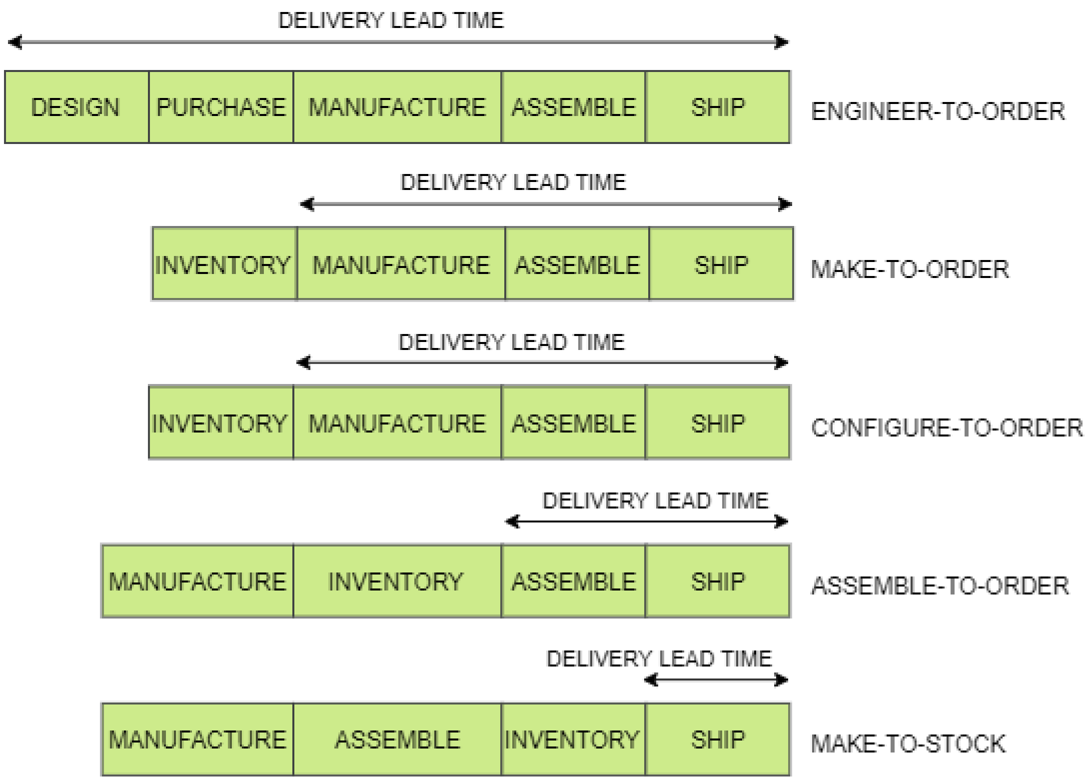


Figure 7. Delivery lead times compared to manufacturing strategies (Chapman, et al. 2017, 1).

2.5.1 Make-to-Stock

Make-to-stock manufacturing strategy is when the manufacturer puts the ready finished goods in the inventory. (Zuyderduyn, 2011). All lead times in terms of raw materials delivery to plant, production, assembly and stocking in inventory are non-existent. It has the shortest lead times and finished goods are ready to be withdrawn from the inventory. (Chapman et al. 2017, 15.)

2.5.2 Make-to-Order

The second manufacturing strategy is make to order strategy. In this strategy, the manufacturer does not start the manufacturing nor assembly processes of the goods until the customer order is made. Only when the order is created, the manufacturing and assembly will start. Manufacturing, assembly of the goods and shipment lead times are all lead times that are present in this strategy. (Chapman et al. 2017, 15.)

2.5.3 Assemble-to-Order

The third strategy involves products that are already manufactured. Such parts can be standard parts that can be later assembled. These parts are typically stored in the inventory and are waiting for the customers order in which case they are withdrawn from the inventory to the assembly line where the goods are assembled, and finished goods are then made. Lead times are assembly line and shipments to the end customer. (Chapman et al. 2017, 15.)

Hilti plant 04 uses assemble-to-order strategy in the assembly line and make-to-stock strategy in the production site of the factory. In the production facility components are produced at constant rate to keep machining utilization at the highest and to produce safety stocks of components. This is the way Hilti responds to unscheduled production orders caused by demand fluctuactions and prepares for seasonal demand spikes.

2.5.4 Engineer-to-Order

Engineering to order is a strategy where the customer needs a specific designed product and works together with the manufacturer in order to produce it. It takes a lot of time until the finished product arrives to a customer. Lead times are from the designing phase all the way until the finished goods are delivered to the end customer. (Chapman et al. 2017, 15.)

2.6 Production flow and sequencing

When the total jobs are in the system or ERP system, the managers need to decide which jobs should be completed first.

Sequencing allows managers to take right decision relating most critical materials and prioritize production techniques (Heizer, Render & Munson 2017, 611).
According to Heizer (Heizer et al. 2017, 611), the priority groups depend on what criteria needs to be met first. To minimize number of jobs, job lateness, to maximize utilization and completion time, there are four most popular priority groups that are used in industries:

- First Come First Serve
- Shortest Processing Time
- Earliest Due Date
- Longest Processing time

FCFS (First Come First Serve) means that jobs are sorted in an order based on first order that came in. It is then prioritized as a first order that needs to be completed. (Heizer et al. 2017, 611) First Come First Serve is also known as **FIFO** (First In First Out) (Techopedia, n.d).

SPT (Shortest Processing Time) is when jobs that are with the shortest processing times are prioritized first in the system. These orders are completed first and longest processing time jobs are prioritized as last. (Heizer, Render & Munson 2017, 611.)

EDD (Earliest Due Date) is when jobs are assigned based on their due date times. The production starts only when it is closest to the last day of the day that production needs to start. (Heizer et al. 2017, 611.)

LPT (Longest Processing Time) means that the jobs which have the longest production times are completed first.

First in First Out System is used at the plant 04 since material flows are growing increasingly complex. Because of that, prioritization was required to keep the output simple as possible. Based on FIFO prioritization, managers at the plant have a clear track on required productions for the week.

3 INVENTORY MANAGEMENT

Everyone uses inventories daily without thinking about it. By purchasing food in a store based on personal requirement, a customer does not necessarily buy in bigger quantities by the reason of the spoilage of the product if is not consumed in time. The product spoilage results in the financial loss.

Inventory by its definition means the amount of goods that are available for the further use or as a ready product to be sold (Aswathappa & Bhat 2009, 462).
Having an inventory is necessary regardless of the size of the organization. Inventory consists of goods that can be classified of set of products that are of different stage of the production. (Investopedia n.d). In an inventory, raw materials exist so that they can be processed to subparts or in non-complex operations, to finished parts. Subparts are parts that are constructed from raw materials and other subparts that are ready to be processed further in different operations. Finished parts are parts that have undergone a certain process of operations and are now ready products for sale. (Aswathappa & Bhat 2009, 463.)

There are many advantages of having a sufficient inventory system. First, it acts against fluctuations of demand, meaning that the organization can prepare itself against non-controllable factors. The demand may drop, or it may increase. Organizations may experience seasonal changes in the markets when demand for products might be higher. This is called a seasonal demand. (Stevenson 2015, 549.) For example, the demand for Christmas trees in winter is higher, whereas in the summer the demand is close to zero.

Another important reason to have inventories is to better meet the customer demand. This is called an anticipation demand (Stevenson 2015, 550). If a customer wishes to purchase a product but the company does not have that product in stock, the company loses a client and therefore income. These scenarios are not desirable for an organization because they lead to loss of profits. Additionally, overstocking inventory might accumulate loss of profit. Food industries are prone to such risk due to the limited shelf life of food products. And understocking might lead to losing a customer or if there is no availability of material, it might lead to a complete production halt at an industrial organization.

Having an inventory of products at different stages permits the production operation processes and keeps the cost of production low. (Aswathappa & Bhat 2009, 464.) Having parts for different production operations is essential for a manufacturer. Subparts may require another subpart to assemble a final product.

Inventory can also help to isolate suppliers, producers or suppliers. (Aswathappa & Bhat 2009, 464.) Inventories may be used as buffers in order to have their own production processes which act as a buffer between sets of operations. Independency in production schedules limits the risk if for example a machine breaks down that leads to a production halt. This enables machines to continue production until the maintenance of another machine is done. Additionally, having a buffer in inventory, protects the manufacturer in case of materials orders delivery coming late. Although according to just in time theory, inventories are considered as a waste, having calculated buffer of materials protects against the disruption in production operations. (Stevenson 2015, 550.)

There are advantages and disadvantages depending on the inventory levels. The excess inventory ensures a better answer to the customer demand including the conditions of rapid demand fluctuations. As well as the elimination of complete stockouts of products. Customers can get their products faster due to existing inventories. In addition, transportation costs of bigger batches are lower compared to transportation costs of smaller batches. Ordering costs are also lower since orders are infrequent.
The biggest disadvantages of excess inventories are holding costs and insurance costs. It is expensive to have big inventory levels of materials. Materials take a lot of space and depending on a product they require a storing facility. An excess also increases chance of items becoming obsolete due to the large amount of quantities, which eventually accumulates to revenue losses. (Chapman, Arnold, Gatewood & Clive, 239, 2017.)

3.1 Inventory types

3.1.1 Raw Materials

Raw materials are inventories that are transformed to an end product through a production process. The production process can be extensive or simplistic depending on what is produced. Raw materials can be extracted by a manufacture company itself or procured from a supplier.

Procured product can also be called a raw material, even if its subassembly part of a product. (Inman, n,d.)

3.1.2 Work In Progress

Work in progress materials are subassemblies, assemblies or parts, that undergo a certain production process stream of transformation. For example when a car manufacturer produces a tyre from subassembly, that part is called a working in progress material. (Inman, n,d.)

3.1.3 Finished product

A ready product that is ready for sale is classified as a finished product. These products are the outputs of working in progress materials which underwent a production process and passed the quality control inspections. Finished products essentially products that moved from work in progress to finished parts inventories. (Inman, n.d.)

3.1.4 Transit inventory

Transit inventories are materials subjected to a movement from place A to place B. Various transportation modes can be used. Transportation solutions can be road, rail, sea or even pipeline transportation methods. (Inman, n,d.)

3.1.5 Safety stock

Safety stocks are used by organizations to better prepare for the fluctuations of demand and supply. Buffer inventories main function is to assure the availability of materials that are required either for production or to meet required customer demand. In manufacturing companies there might be parts that are required for the production and production is not allowed to stop. In this case the availability of materials plays a critical part of production operations.

Safety stock amount is the left-over extra inventory that is left between reorder point and the time of the delivery of the goods. It gives extra time for the delivery and protects against a complete stockout of materials. (Inman, n,d.)

To calculate the right amount of the required safety stock, organizations must consider lead time of product, demand of the product and determination of the reorder point. Reorder point means the point at which the order of the materials is made, and the lead time is calculated the time made between the reorder point and the delivery time.

3.1.6 Anticipation inventory

A demand that changes in patterns throughout the year is called seasonal demand and it fluctuates in patterns. Most commonly this is used by retailers. For instance, shorts do not have much demand in the winter time, whereas in summer it is hard to sell winter jackets. Retailers build their inventories in quiet season when the demand is low and maximize their cost efficiency by buying products in the lowest prices.
Manufacturers use anticipation inventory to avoid excessive production time and smoothing the production throughout the year. Additionally, keeping machines running always and work force occupied during slack times, minimizes the setup costs and adds efficiency. (Inman, nd.)

3.1.7 Decoupling inventory

Manufacturing companies often have many operational machines that produce on a constant basis. Some machines depend on other machines outputs and some dont. Decoupling inventory means that production operations are smoothed out even during a maintenance or repair of another machine. It is the stock produced by a machine that is available for the inputs of another machine. These inventories are functioning as schock absorption and enable continuation of the production process for a limited time. In other words the production process is smoothed out and decoupled inventories are there to prevent the production full stop. (Inman, nd.)

3.1.8 Cycle inventory or lot size inventory

Inventory cost is more expensive when inventories stocks full. This occurs either by purchasing stocks or by producing large quantities of stock. The result of larger inventories is decreased ordering and production costs but increase in inventory expenses.
And vice versa, when inventories decrease, the inventory becomes less expensive but ordering and production costs are high. The balance is achieved by Economic Order

Quantity model, which attempts to balance the effect of incurred costs of inventory and set up times of machines or ordering costs. The cost is minimized when costs of inventory and ordering or production are optimized as equal. Cycle inventory results when excess materials are ordered and held in inventory at minimum stock level. The results of cycle inventory is occuring because of orders that are in batches. (Inman, nd.)

3.1.9 MRO inventory

MRO is abbrevation of Maintenance, Repair and Operating supplies. The function of this inventory is to keep the production process at constant. MRO's are not result of the end product made by the production itself, they are however there for maintenance of machines and repair purposes. In the production line, for example oils, lubricants, machinery tools that are related to the production are part of these ivnentories. Additionally, office supplies such as pens and paper blocks are considered as MRO inventories. (Inman, nd.)

3.2 Inventory costs

Costs of inventories are broken down to 4 categories that sum the costs of the inventories. Such costs that are considered as expenses of inventories are: **holding costs**, **purchasing costs**, **ordering costs** and **shortage costs**. (Stevenson 2015, 554.)

Holding costs are costs that are associated with goods, that are stored in a warehouse and are on hand amount. Costs are accumulated by the quantity and the type of goods. Typical costs are for instance electricity, insurance, spoilage, depreciation, obsolescence. These costs are subjective. Electronic parts and components require room temperature, not to get damaged by too hot or too cold climate. Food products are prone to spoilage. If temperatures are not low in the warehouse, food may spoil much faster and can cost a company a lot of money. The larger the inventories, the larger are the costs and higher liabilities. (Stevenson 2015, 554.)

Purchasing costs are the amount that are paid to the vendor or supplier to fill the inventory with goods. The costs are the costs associated with the inventories incurred by materials or components. (Stevenson 2015, 553.) According to Stevenson (Stevenson 2015, 553), purchasing cost is typically the biggest cost of thee associated costs of inventory.

Costs that are accumulated by ordering and delivery processes are called **ordering costs**. These costs result when an actual order is executed. Once the order is made, costs start to accumulate. These costs are: inspection of goods before and after they arrive, preparing invoices, the quantity of goods upon order, movement of goods to a temporal holding. (Stevenson, 553.)

One of the biggest misconceptions of having low inventories is the idea of low inventories equal to low costs. While that to some extent true, it is not entirely the case to constant fluctuations in demand and supply. It is often very hard to determine the precise amounts of inventories required to avoid overstock or understock of goods in inventory.
Having no inventory or having insufficient inventory leads to **shortage costs**, which is one of the main underrated costs, but also very hard to find out because the shortage costs are subjective. (Stevenson, 553.)
A company experiences shortage costs when the demand is higher than forecasted or anticipated demand. And when a company cannot answer the demand it leads to lost in sales. Somewhat more serious scenario is when a company loses a customer. Since the logistic costs are always higher for the express logistics, the costs are increased if a company tries to respond to a situation where shortage of goods incurred. (Stevenson, 554.)

For a manufacturing business the consequences of having too low inventory levels while demand is high can be problematic. The requirement of materials for the production are needed as soon as possible, which increases the procurement rate of the materials. The logistic expenses are also increased due to the faster delivery to the plant and the ready parts to the customer. Furthermore, the changes disruptive operations caused by rescheduling in machining causes problems. Inventories are temporarily increased which require extra space and operations in assemble line also would require changes. In addition, more workforce is required to complete the customer order.
Overall, the shortage cost can be more expensive than having a sufficient and well-planned inventory levels. (Stevenson 2015, 553.)

3.3 Classification of inventory

Sometimes stocks consist of products that are different in their monetary value. An inventory could consist of a lot of product A, while less in quantity of product B. However, product B might worth much more than product B and therefore its more valuable for a company to keep an exact track of product B. (Stevenson 2015, 554.)

The importance of classifying stocks in inventories serves multiple purposes for a company. First, if items are classified and stored properly, they minimize the unnecessary moment in inventory meaning that the personnel always know where items that whether they need them. The extraction of products at their exact position saves a lot of time and brings smoothness to inventory processes. Second, items might be classified according to their importance. Frequently used items might be placed close to an exit door, rather than in the middle of inventory. By doing so it is logical to take items fast, rather picking them up from the middle or the back of inventory which only adds to time lost.
Third items need to be counted to find out the exact number of items that are stored. Despite of the fact that nowadays the track records of inventories are done by software, there might still occur mistakes which result in false inventory information. Inventory counting gives a precise number of items that are currently stored to keep an exact track of items. Additionally, this information is required to calculate the beginning number of stocks and the end amount of stocks to count. (Stevenson 2015, 555.)

3.4 A-B-C Inventory analysis

As mentioned before, the importance of counting is crucial to a company to keep the exact track records of items stored. This eliminated discrepancies and of inventories by showing the exact number of items that are at hand. Moreover, this information is important to a procurement process, where it is necessary to know the reorder point of products. By being proactive in inventory, a company can save a lot of money of having an efficient inventory system. By calculating the safety stock levels, it is possible to distinguish a reorder point of materials.

Cycle counting helps the inventory manager to calculate the exact amount of goods. Cycle counting should be used at least once per year. If there is a big in and out flows of goods in inventory, cycle counting can be increased. (Stevenson 2015, 556.) The idea of it is to find out the exact amount of goods at hand, to give right data on re order points.

To conduct an ABC analysis of inventory, first there should be a rule to set the parts in their order. Classification can consist of monetary value, frequency by which most required items are listed as most frequently used for the production or other means of value. A category means highly important materials, category B is moderately important materials and category C means least important materials. A company can adapt more segments like DEFGHIJ etc.
A company might have a lot of materials or products at stock, and typically it takes a long time to count all the items at stock, therefore it is first important to count the most important items at hand because they amount to higher values. The counting of parts in A segment might be increased, while least important items in C segment can be set to be counted only once or twice a year. This way, a company knows the exact monetary amount of its inventory. Cycle counting should be consistent to eliminate the discrepancies of the current stock levels in the inventory and keep inventories accurate to avoid disruption of production and minimize carrying costs. (Stevenson, 2015, 556.)

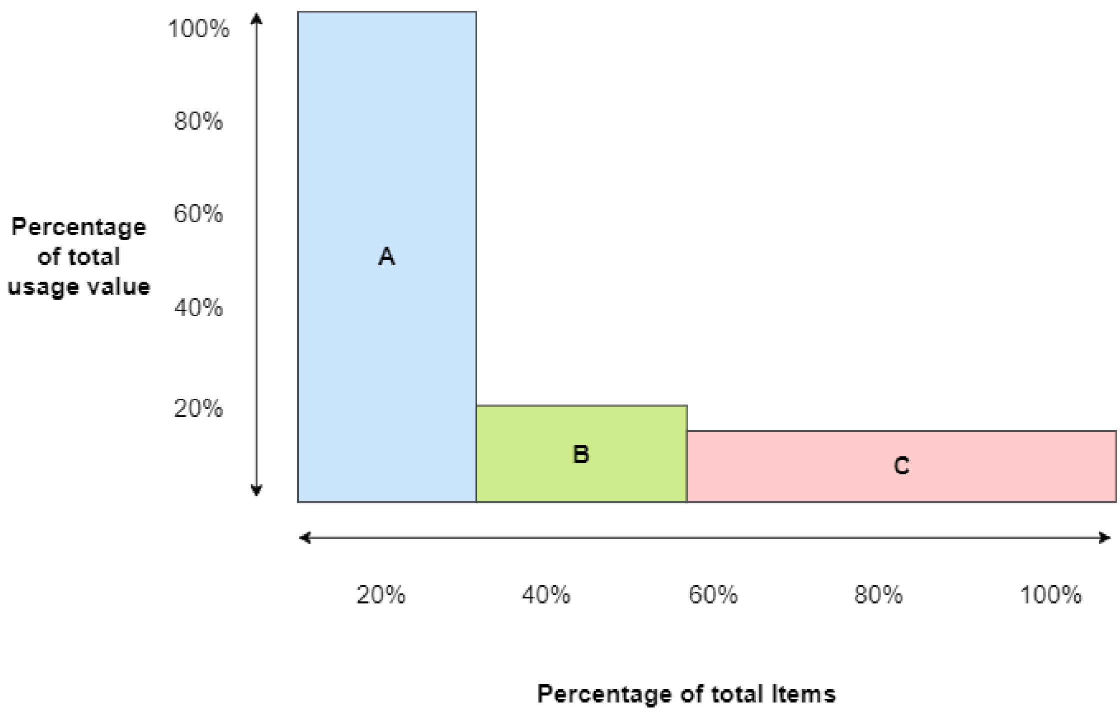


Figure 8. The number of items compared to their value (Stevenson, 2015, 555)

Some products are finished parts, some subparts and others might be raw materials. It is essential to count items to compare the beginning inventory with the ending inventory.

Sometimes it is necessary to count items even if the counting was conducted by a computer. It is good to update the inventory levels to keep certain accuracy.

3.5 Economic Order Quantity

Economic order quantity (EOQ) is a formula which calculates when to place an order for the inventory. It tells when to buy and how much to buy to avoid overstocking and understocking. As mentioned previously in the inventory section, overstocking leads to spoilage or obsolescence and increased storage costs. This essentially translates to the financial loss. (Slack, Chambers & Johnston 2010, 349.)

EOQ strives to optimize the costs that are associated to purchasing, ordering and carrying cost and balances all the costs to minimize the total costs. (Slack et al. 2010, 349).
The basic calculation method is displayed below.

$$\textit{Total cost} = \textit{purchase cost} + \textit{ordering cost} + \textit{carrying cost}$$

Based on the given example, is evident that the Economic Order Quantity suggests procuring 350 units at a time. Total costs are at lowest point, when holding costs are at the lowest point compared to ordering cost.

	unit amount	2,000 €	
Order cost	per order	30 €	
Holding cost	per item/year	2 €	
Order quantity	Holding costs	Ordering costs	Total costs
50	25	1,200 €	1,225 €
100	50	600 €	650 €
150	75	400 €	475 €
200	100	300 €	400 €
250	125	240 €	365 €
300	150	200 €	350 €
350	175	171 €	346 €
400	200	150 €	350 €
450	225	133 €	358 €

Figure 9. EOQ cost example

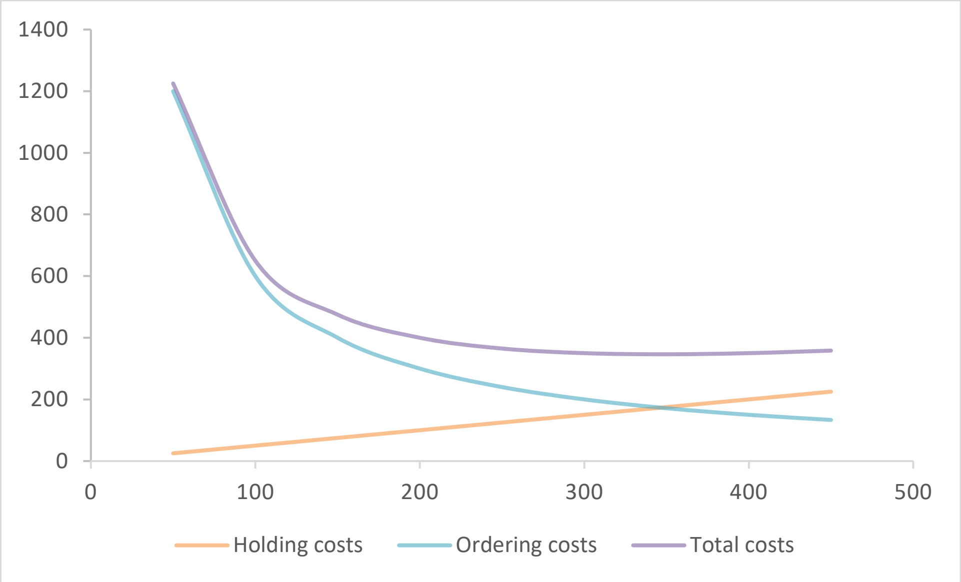


Figure 10. Optimal reorder point vs. ordering and holding costs (Stevenson, 2015, 786)

3.6 Reorder point

The reorder point is a point, at which the order the materials should be placed. While EOQ is used to calculate the amount and quantity of products, it does not show when to place an order. Therefore, to find an exact reorder point it is important

To find out the reorder point of materials to avoid a stockout due to the demand, it is necessary to know the following, a reorder point calculation is required. (Stevenson 2015, 569.)

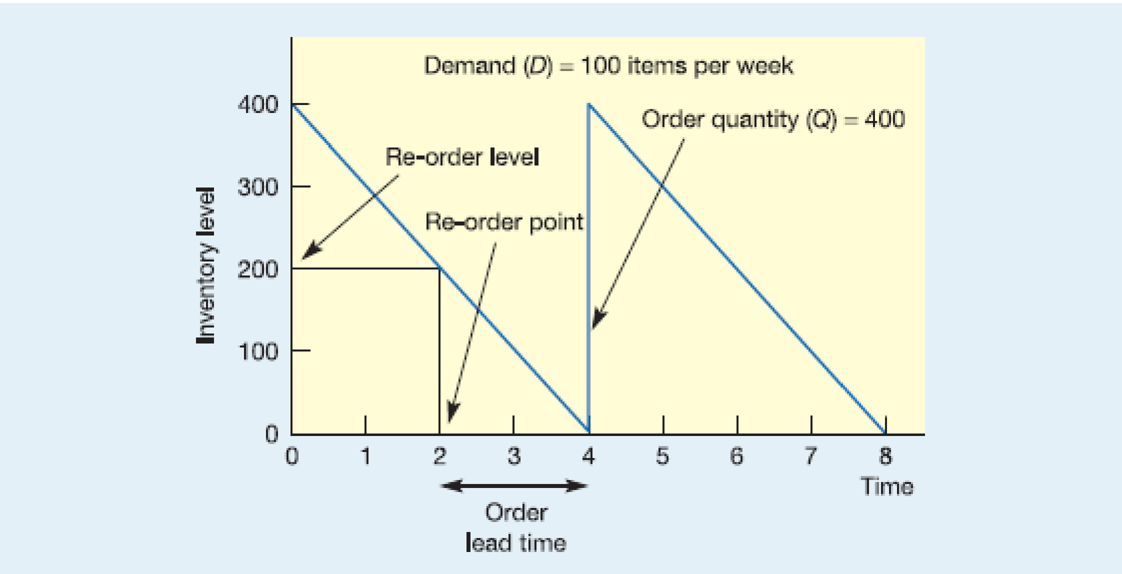


Figure 11. EOQ model considers re-order quantity and lead-time (Slack, Chambers, Johnston, 2010, 358)

4 LEAN MANAGEMENT

4.1 Lean production method

Production operations have changed drastically during certain periods of time. Companies used mass production methods to produce goods without consideration of the requirement of the large inventories. The operations were complicated and accumulated a lot of costs. Larger assets mean often higher liabilities. In addition, when stacking large amounts of products in inventories, products are subject to obsolesce of complete loss of products. Just like it was already mentioned, goods like electronic parts are fragile and even small change in the temperature may cause them break. Another example are food products that depreciate with time and thus result in loss of financial losses. (Stevenson 2015, 607.)

Since the drastic change of the manufacturing processes in the past, when the companies used the mass production methods instead of smart production, a lot of inventories and inefficiencies. Production was focusing on mass production and often resulted in accumulated costs and inefficiencies. The costs for instance, occurred of overproduced parts and components, which grew the inventories size, making holding costs expensive. The inefficiencies of production occurred due to the lack of performance measuring and the lack of improvement of operations. (Stevenson 2015, 606.)
LEAN thinking is the tool created and developed by Toyota, in order to increase the efficiency of the production and to minimize production accumulated wastes as much as possible. The aim of LEAN method is to improve production by making it more cost-effective and to eliminate all the steps in the production that eliminate task time, by using the pull method. In LEAN, the production is only starting when the customer makes an order. (Stevenson 2015, 607.)
LEAN in Hilti, short lead times increase the company's competitiveness. Eliminate non-value adding activities, from customer, value stream and to the customer. (Hilti, n.d.)

To understand what a pure LEAN system is, it is important to understand the core ideas and values of this system.

1. **Waste reduction** - This function strives to reduce wastes whenever possible. This can be for example time setup waste or material waste which is formed through the production processes.
2. **Small lot sizes** – Adds greater flexibility to the production and ability to produce only if there is a demand created by the customer
3. **High quality** – Support customers demand by creating value to the customer and greater satisfaction with the product.
4. **Minimizing inventories** – Large inventories of materials or parts are classified as a waste in lean.
5. **Continuous improvement** – The improvement processes are never ending and there is always something to make more efficient. Improvement focuses on solving inefficiencies and eliminating them.
6. **Strong teamwork** – A function which improves communication within the organization.
7. **Culture of LEAN** – responsible functions which requires everyone's attention which aims to solve arising issues together as one big team. (Stevenson 2015, 606.)

According to Stevenson (Stevenson 2015, 607), there are benefits as well as risks which are associated with LEAN systems.
The most important benefits are:

1. Waste reduction
2. Reduced costs due to lower inventory levels as well as low wastes
3. Strong customer focus and high-quality standards
4. Reduction of non-value-added operations and an increase of value-added operations which results in greater productivity levels and reduction of all needless actions
5. Greater flexibility of operations due to the small lot sizes

Some of the risks that are associated with the LEAN concept are:

1. Production can be halted if the supply chain disruptions occur. This can happen if the inventory levels are low or miscalculation of buffers in between operations and lead times.

2. Increased responsibilities and higher stress levels can affect workforce negatively
3. The reduced amount of workforce as well as inventory levels are often hard to deal with and fast reaction is difficult

4.2 House of lean

House of lean is the combination of principles and combined activities backed by theoretical assumptions that form a strong foundation of practicalities with a goal of bringing the most value to the customers by eliminating inefficiencies in operations without sacrificing the quality output. (SAFe, 2017.) The goal of this system is to bring the most value to the customers by having the highest quality and having lowest possible lead times. The reason why house of lean s called a house, is because in order to have a strong LEAN system, it is first important to have supportive pillars and a solid foundation in order to bring the added value to the customer. (Bradbury, nd.)

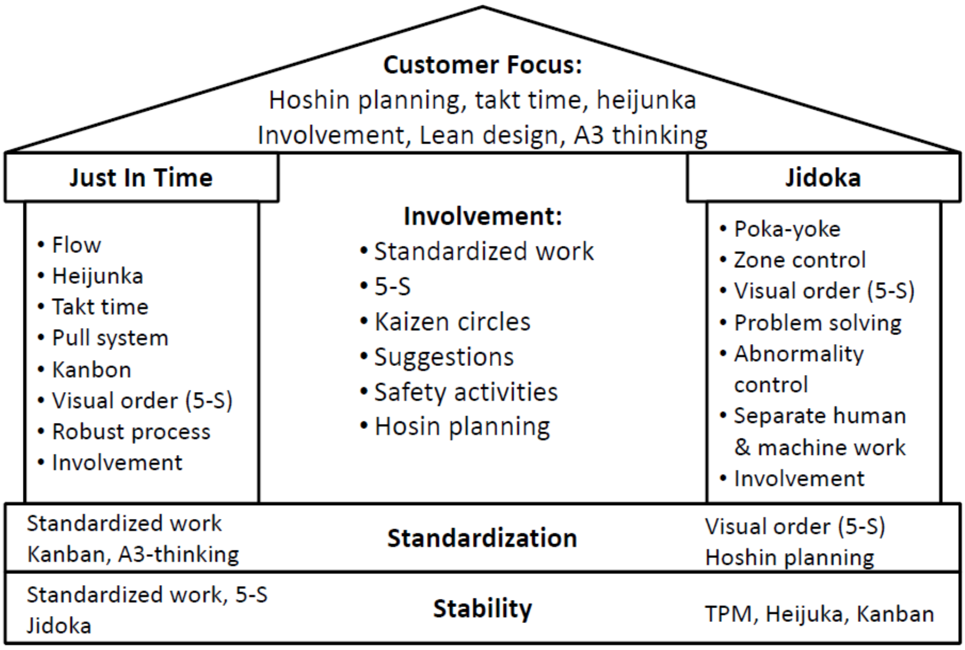


Figure 12. Foundation of House of Lean (SAFe, 2017)

4.2.1 Involvement

Involvement factor is the first pillar which is in the canter of the house. Its basic functions are to find out the core purpose of the ongoing operations. This function is important because it identifies the core belief. It aims for internal change and is supported by the strong leadership, effective management and coaching, trust among the people within the organization, proactive engagement and continuous improvement. Such supportive tools are for instance standardization of work by implementing different standards and procedures, kaizen tool, and 5s operations (Bradbury, nd.)

4.2.2 Standardization

The standardization aims for implementation of strong know-how at work, while taking in considerations the exact work functions and standards to eliminate the failures occurred during work related operations. The improvement of work-related processes is important, because it increases the value streams and minimizes the mistakes and saves time. The tool that is used for standardization operations is 5S tool, which helps in achieving stability by implementing variety of standards and thus improving productivity and accuracy of the work which minimizes the mistakes. (Bradbury, nd.)

4.2.3 Supportive walls

The walls are the supportive function of production related operations. These functions are crucial for the efficiency of operations, productivity, quality management, on time production completion, production control and planning and production levelling. (Creative safety supply, 2018.)

Optimization of production can be thus controlled with the card systems like or Kanban systems. The order is made only when the customer pulls an order and the production is only started according to the pull effect. Raw materials are only purchased when the customer has placed an order and the requirement of raw materials begin.

The result of the production operation systems according to Hilti are

- Output is optimized
- The use of work space is optimized
- Underproduction or overproduction is minimized

- WIP production is decreased

4.2.4 Material flow types

Push versus pull methodology is related to the LEAN concept. In pull method, the production order is only made according to the customer order. If there is no demand for products, pull method cannot function. In push method, the production orders are made regardless whether the customer orders are created or not. The focus is on production orders principle. (Industry Week, 2017.)

4.2.5 FIFO

The more complicated production operations are and more quantity of parts, then more difficult it is to keep a track of inventories of those finished parts. In addition, poor optimization of sequencing increases a risk of increased inventories and delays of finished goods. (Lean Enterprise Institute, n.d.)
FIFO stands for First-In-First-Out is a sequencing strategy, which offers to keep a track of materials that entered the production. Essentially this method pushes the first part that entered the production line, and which is also the first part to be finished. (Lean Enterprise Institute, n.d.)

4.3 Production methods

4.3.1 LEAN at Hilti plant 4

LEAN enterprise helps the organization to achieve their goals, which include customer satisfaction, improved flexibility and increased reliability in delivery performance (Lean@Hilti, n.d).

Hilti plant 04 has adopted the LEAN strategy only just few years ago and has been successful in the implementation of this technique. The decrease of waste and non-value adding activities have decreased and operations are now smoother. In addition, there are weekly and monthly waste management meetings, that are aimed to further decrease the wastes and adapt new activities that help the organization to cut non-valuable added activities.

Hilti LEAN guidelines state, that Hilti is actively working on further implementing LEAN functions and have set a goal by 2020. According to Hilti champion strategy 2020 (Hilti, nd), LEAN is actively implemented in direct areas: Logistics and production, but also in indirect areas within the framework of the whole Hilti professional environment. (Lean@Hilti, nd.)

4.4 Kanban

Kanban is a tool that is utilized at the shop floor level. It is a card-based system, that tells which material is next assigned to a new function (Lean@Hilti, nd). It is a tracking system that has all the necessary of the identifications on a card and shows the information of what material it is, where is it coming from, where is it headed next and what is the quantity (Chapman, Arnold, Gatewood & Clive 2017, 401).
The simple purpose of this system is to assist LEAN production processes by moving materials from place A to place B in relatively small containers. This means that this system can trigger reorder points much faster than the formal highly structural system. (Chapman et al. 2017, 401.)

This system has also been adapted at Hilti plant and there are plans to further implement this system to other parts of the production within the facility as further increase LEAN method.

4.5 Just-in-time

Just in time method is a tool developed to ensure to have right products at the right time at the right place with the right quantity. It assumes the constant flow of goods, that enable the availability of materials at the right size and the right time at the right location with a right quantity. Just in time tool requires frequent flow of products with smaller batch sizes. The problem quickly arises, when the suppliers are not able to deliver the product at exact required time due to the fluctuations of the demand which are hard to forecast. The disruption of the planned operations at the plan are difficult to reassign and require attention when ether the right materials does not arrive in time. The disruption of the flow of right materials at the right time may lead to unavailability of goods that needed to be produced according to a production schedule. Parts available lead to an incorrect production schedule. (Lean Enterprise Institute, n.d.)

4.6 Heijunka

Heijunka is a production levelling method which is used by manufacturing companies to ensure the smoothening of the production. The benefits are better preparation for the aggregated demand which changes constantly and better machine utilization as well as rapid answer to the demand. This enables to utilize the machines and equipment as well as work force smoother compared to just to produce when the demand is there. The concept of Heijunka is extremely useful for a manufacturing company because it allows the evening out of operations, thus keep the machining operations as constant. The biggest benefit however is to minimize the demand fluctuations and thus to be ready to answer the demand much faster by having a little of existing parts in the inventory. Additionally, it builds a buffer between machines when the parts enter second and third operations.
The outcome of Heijunka is that it creates a safety stock inventory, to incise of the demand fluctuation. (Lean Enterprise Institute, n.d.) For example, if the demand for January is 10, and for February 5, the production should me 7,5 plus additional safety stock amount, which can be 8.5. In total we would have still 1 as a safety stock, to prepare for possible fluctuations. Heijunka assumes, that if there are more quantities needed to be produced, it is possible already to start production earlier by producing a constant flow. Essentially it is proactive system, rather than reactive. (Lean Enterprise Institute, n.d.)

4.7 Kaizen

Kaizen is a production system strategy in which all employees of the organisation are participating in achieving improvements of the manufacturing processes. It is a proactive rather than reactive system, which enables management as well as shop floor level workers to work together to achieve regular improvements of processes which helps the overall manufacturing efficiency. (Chapman, Arnold, Gatewood & Clive 2017, 405.)

5 ERP SYSTEM

Enterprise Resource Planning (ERP) is a broad software that functions as database of an enterprise, that shows the wide range of enterprise data in real time (Heizer, Render & Munson, 584).

5.1 SAP

One of the most widely used ERP software is SAP (Systems, Applications and Products in Data Processing) (SAP, nd).

SAP is playing a major role in the Hilti 04 plant. The systems are integrated internally as well as internally and the information data is stored all the way from suppliers to the customers. The system itself contains wide range of information from the suppliers, orders information, production data, materials availability, HR data, Accounting and Financial applications and customers data.
Materials managers only use the production data, production stock information and materials that need to produce at a given point.

5.1.1 APO SAP

APO stands for Advanced Planning and Optimization and it shows such processes such as Demand planning, Supply planning, Production Planning and Scheduling, Global Available to promise, and transport management data.
The requirement of such data is highly important for materials managers as they need such data to know what parts are ordered or needed to be produced at the given time. (Murray, 2018.)
At the plant 04, APO serves as a forecast software, which tells managers the amount needed to be produced at the specific time. The software already calculates the forecasting data by aggregating the data that was produced in past years and forecasts the future the amount that is needed to be produced. The data itself gives the value that is required in the future and not the amount that needs to be produced now. Typically, materials managers look into security stock levels of materials and if the levels are too low, then they try to prioritize the production of that material.

Apart of being used as a demand planning it is also used as supply network planning, production planning and detailed scheduling as well as Availability to promise.

5.1.2 Inventory Software SAP

At the Hilti plant 04, inventory system is a part of SAP and it is deeply integrated with SAP and APO system. This data is used not only by the materials managers but also inventory managers that are focusing on inventory stock levels, cycle counting and re-calculation of the real amount of the availability currently in the stock.

6 KEY FINDINGS

During the active research at Hilti plant 04 several points were discovered that extend not only to the production operations but also inventory operations and the entire supply chain.

At Hilti plant 04 the production is highly dependent on raw materials on time arrival which enables production to run smoothly within accordance with LEAN production method, FIFO sequencing method and Heijunka levelling method.
The data of raw materials is obtained from APO ERP system which tells the exact quantity of raw materials required for parts to be produced and the time the production should start so that the parts are ready by scheduled date. The software assumes if specific quantity of finished parts required to be ready, the production should start much earlier so that they can be ready on time. It calculates and includes all lead times incurred from suppliers to the plant delivery and the lead times between the production, assembly and the delivery to the end customer.
Materials managers obtain the production data of production orders from APO system based on the production orders. When the production orders are created, and items are stored in the inventory. Production orders start automatically regardless the excess of materials in the inventory and the procurement of raw materials is automatic unless there are some changes in which case additional raw material orders are made. In case of Heijunka, the additional production orders are not as problematic as compared to the yearly production plan. In case the additional production order is created manually, it creates a problematic situation for the yearly plan production because the yearly plan production must be changed, and machines reassigned.

In the beginning of the year materials managers create a fixed yearly production plan based on the information obtained from the APO system and add Heijunka production levelling method for each month to keep the production rates the same each month.
Even that the purpose of Heijunka production levelling method is to keep the production rates the same each month, Hilti slightly raises or lowers the production rates each month due to the seasonal changes of the demand. As a result, production rates of components are lower in the summer and higher in the winter season. This technique helps Hilti to

save unnecessary inventory costs of finished parts or subparts and keeps safety stock levels as minimal but just enough to compensate in case of exceptional changes. Safety stocks are also created, and the main purpose is to keep the buffer between the machines to ensure the smooth production to eliminate the complete stockout of the materials which could potentially disrupt the production process since machines are sequenced and work in a specific order. Safety stocks also compensate the batch production quantities in case the materials do not pass the quality expectations and therefore the additional production order does not need to be created.

In the production line there are some bottlenecks which have the essential influence on the production. The correct management of bottlenecks eliminates excess of work-in-progress materials and enables all machines to run smoothly.
At Hilti 04 Production site there are currently 2 bottlenecks machines which are 3 and 4. The production time of these machines is the longest and currently they operate in three shifts. These machines can build the necessary safety stock quantities, but a possible problem arises if during peak times the demand exceeds, unscheduled production order starts or one of the machines breaks down. Since safety stocks can compensate some of the accumulated production disruption, the maintenance time is very limited and potentially lead to readjustment of the yearly production plan. Machines 3 and 4 can produce enough, but the problem arises during the peak demand or an unscheduled demand of components which happen rather seldom.

Once the production orders are finished at the shop floor level, the finished materials and their quantities are booked directly in to the SAP system. Though materials managers use some of the tracking systems such as weekly discussion at production site about the number of finished or not finished components, they nevertheless do not apply any comprehensive material production tracking, which is available in SAP software. The software itself shows the accurate data which contains information of material numbers, their quantities and other information.

As the plant 04 still does not operate fully according to LEAN method, the leadership is reviewing options to further adapt to this method. The biggest issue currently is the supply chain, which is not always able to cover the raw materials on time delivery when unscheduled production order is made. This is because these suppliers have many customers and while Hilti is a priority, they are still not able to deliver the raw materials.

Especially raw materials that are not so often procured are posing a problem because these orders are made unexpectedly, and suppliers do not have the necessary inventory levels of the required materials on hand.

Materials managers argue that there should be more fixed plan every 3 months in which schedule might change according to such need to minimize or increase safety stock levels of different materials. This is because the safety stocks levels tend to fluctuate compared to the actual demand and Heijunka levelling method. It is difficult to control safety stocks by the reason of their higher levels during periods when these stocks are not on a high demand and therefore it allows the management to keep the due level of production during the periods in which there is a higher demand for these stocks.
High demand for the stocks depletes the safety stock levels making them low and decreasing the flexibility in the production line.
In other words, those bottleneck machines must produce those materials that are at the highest demand and therefore change the production schedule.

At the Hilti plant 04, materials managers focus on day to day production activities that are related to the production operations, materials availability and capacity measurements. Although the production plan horizon is 1 year, the production plan is reviewed or changed every 3 months due to Heijunka production levelling method, which helps to smoothen the production leveling in case the forecasts are inaccurate. This approach has proven to be efficient, if for instance, the demand is higher than forecasted, in which case the demand could still be answered due to the existing buffer of goods.

7 PROPOSALS AND CONCLUSION

Based on the outcome of the findings, there are several ways to improve the on-time arrival of the raw materials of unscheduled production orders and on-time production of scheduled components.

7.1 Suppliers network and LEAN management

Hilti's customers are its core business. Adaptation of LEAN method and other related processes are backed by strong leadership that enables the plant to operate efficiently while keeping a strong customer focus. However, there are several issues that are posing a challenge to the plant. These issues are supply chain network, high production outputs during the peak season and unscheduled production orders.

Increasingly complicated supply chains affect the raw material availability due to increasing flexibility at the plant. The current availability of raw materials on-time arrival and complicated suppliers' network is a challenge to the company.

To further contributing to better response to customers and to curb unexpected needs, it is requirable that Hilti increases its focus on various suppliers which could deliver required materials for unscheduled times. By having right amount of raw materials at right time, the lead time of raw material delivery shortens and further enhances the flexibility of the plant by shortening set up times of the machines and helps to reallocate the production plan.
This also backs pure LEAN method, where even sudden market changes of a demand help the production against such sudden changes. Fully implementing LEAN method will among other things contribute to more outputs, increase customer satisfaction, lower the inventory levels and contribute to higher profits.

7.2 Extensive production tracking and reporting

Hilti plant 04 currently does not use any tracking tools which could give them better abilities to get information about the produced components.

Implementation of component could provide materials managers with the quantity data to related to the produced and required parts to achieve the monthly production requirement according to Heijunka. Additionally, the tracking list of made components could include the data relating the amount of time taken to produce components which could make the production more flexible and compensate unscheduled production orders. Whenever unscheduled production order is placed manually in the SAP, the managers could evaluate the time required for the production materials to be ready and if the compensation of other required materials that follow the yearly plan production have enough safety stocks.
The list should be available in SAP system and could be extracted in Excel which would show the exact values whenever unscheduled orders occur.
Keeping a better track and control of the amount of parts procured during the previous week as well as knowing the exact amount of the produced parts would make possible to calculate the overall monthly production according to the Heijunka production leveling method. It could provide a benefit to the materials manager as it would be possible to adjust or reallocate the production by adding flexibility.

Extensive production tracking mechanism example is provided in the Appendices section of this thesis. It contains production outputs during each week by calculating the cumulative amount of the articles as well as target contains monthly target goal of the production. Each graph is visualized according to article number which shows the amounts of the production at the selected date. This excel file enable managers to extend their flexibility and help them in their production related decisions.
The excel file containing the real data has been provided to Hilti and real data will not be included in this thesis.

7.3 Bottlenecks

Since inputs are greater than outputs for Machines 3and 4 only during biggest peaks of demand, it is possible to build larger anticipation inventory of components included in the yearly plan production. The rest components which are planned rarely or most frequently appear as unscheduled components are then outsourced. By outsourcing these components, Hilti can focus on production of anticipated components and with larger batches of components while reducing machining set-up times or to become more flexible producing only the planned components that are already included in the yearly production plan.

Unscheduled components should be outsourced. That way the plant can focus on already planned schedule and stick with the fixed production schedule. As this would eliminate machining set-up times and unnecessary rescheduling of fixed production plan. Whenever unscheduled production plan starts according to APO system, it can be then generated to outsourced entity which starts the production according to a production request.

Other option is to extend working hours on weekends during peak season which would increase the outputs of both machines the demand is larger, and inputs exceed production outputs resulting in production delays.

There are currently two bottlenecks in the production line. Now these machines already run full time in three shifts and they are no more able to produce buffers of certain components. It is also very difficult to reallocate the production for these machines if there is an unscheduled order booked in SAP. If these machines could not anymore produce buffers, it would mean less flexibility and a tight schedule. FIFO strategy would also suffer in case of failed batch that could not pass quality control and buffers between machines could not be any more compensated. It would mean that the parts would be needed to be produced again and by doing so, FIFO would push the orders back resulting in a delay of the production. To counter this, an additional machine is required to help curb these unexpected production orders and ever-increasing demand levels of the production where there are more inputs compared to outputs. The investment in a new machine should only be considered as the last option. If inputs of machines 3 and 4 are bigger than outputs during peak seasons after introducing the weekend work, the improved raw material availability and production tracking as well as the consideration of unscheduled production outsourcing, then the investment in a new machine should be discussed with the managers.

7.4 Inventory counting of stored parts

The current track of inventory levels is efficient. However, the only material counting happens once the raw material or a component is entering the inventory. Counting does not happen once the component or a part leaves the inventory. It is only booked within the SAP inventory software. As a result, there are sometimes discrepancies of the real on hand amount of goods stored in the system.

This could be potentially solved with the tracking both ways. Both when the good enters the Inventory and it is then booked in the SAP system and when it is leaving the Inventory system. Ideally, this would mean that cycle counting could become even easier and less time consuming if we know that x amount entered the system and x amount exited, therefore on hand levels are x amount. In this case the exact number of entered the inventory components is equal to the outflowed number of components so that the result would be 0.

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8 APPENDICES

Auftrag	Material	Materialbezeichnung	ArbPlatz	Gutmenge	Erfaßt	sto	Nr.	Wareneingangsmenge	WIP
				250	02/01/2018		1	1,185	0
				300	04/01/2018		1	1,185	0
				300	05/01/2018		1	1,185	0
				150	02/01/2018		1	579	0
				200	03/01/2018		1	579	0
				1	03/01/2018		1	840	0
				400	04/01/2018		1	840	0
				99	05/01/2018		1	840	0
				20	03/01/2018		1	570	0
				200	05/01/2018		1	570	0
				200	02/01/2018		1	2,050	0
				300	03/01/2018		1	2,050	0
				1,000	05/01/2018		1	2,050	0
				1,200	03/01/2018		1	1,200	0
				3	02/01/2018		1	1,298	0
				4,623				17,021	

Appendix 1. Weekly production output

44	PRODUCTION STATUS		Machine X														
	Paste section	Materials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0	2044180	0	0	0	0	0	0	0	0	0	0	1450	140	0	0	0
	570	2049048	570	950	1150	882	1190	1192	1230	1259	1255	0	0	455	635	687	848
	0	208618	0	0	0	3010	1489	0	0	0	0	0	260	2781	1340	0	0
	0	208981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	2124400	0	0	0	0	0	0	0	0	0	131	994	0	0	0	0
	0	2155073	0	0	2602	0	0	0	0	0	0	0	0	0	0	0	680
	0	2155557	0	0	0	0	0	0	0	0	0	0	0	0	160	580	244
	0	2172346	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1040
	0	2178266	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	23268	0	0	0	0	0	0	0	0	470	339	0	0	0	0	0
	0	23429	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1200	2413	1200	600	0	0	0	1870	1800	580	0	0	260	3340	0	0	0
	0	265138	0	0	0	1285	0	0	0	0	0	0	0	0	0	0	0
	0	275376	0	0	0	494	0	0	0	0	0	0	0	0	0	0	0
	0	275647	0	0	0	0	410	566	0	0	0	340	760	0	0	0	0
	0	275658	0	0	0	0	1225	0	1232	0	0	0	0	0	0	0	0
	0	275688	0	0	998	0	0	0	0	0	0	0	0	0	0	0	0
	0	324243	0	0	0	0	0	0	0	0	0	0	0	0	1290	0	0
	0	324515	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	331047	0	1148	1200	0	0	0	112	0	0	736	2179	585	2915	0	0
	0	359344	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	367000	0	0	2000	1995	0	1435	2150	5043	3886	850	0	0	920	1740	2003
	0	367240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	367244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	367418	0	0	0	0	0	0	0	0	973	0	0	0	0	0	0
	0	380262	0	0	0	800	0	400	400	150	660	0	0	0	0	0	0
	0	380302	0	0	0	0	672	0	0	0	0	0	0	0	0	0	0
	0	381232	0	0	0	100	773	0	450	406	0	0	0	0	240	0	0
	1500	381622	1500	0	0	550	4300	1700	0	0	1685	2315	0	0	20	2870	4690
	3	384947	3	1277	0	0	0	20	0	0	0	0	0	960	233	80	0
	0	386798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

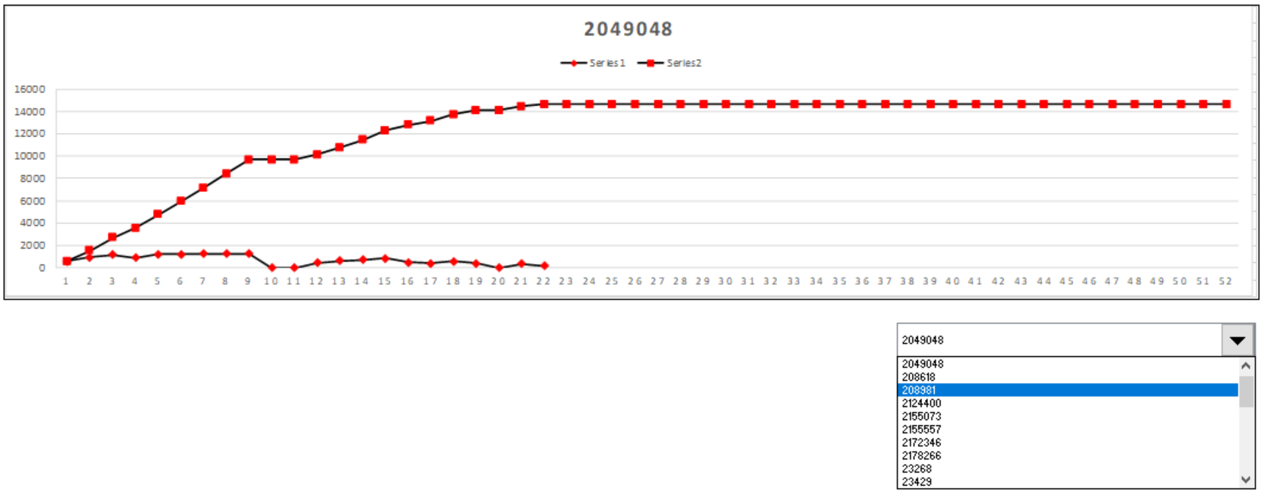
Appendix 2. Production outputs of materials on a weekly basis

[redacted]							
16	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
0	0	0	0	0	0	0	1590
482	389	578	371	0	360	170	14653
0	0	1100	4389	0	800	1461	16630
0	1320	515	363	0	0	0	2198
1742	366	0	0	0	0	0	3233
600	0	0	0	0	0	0	3882
0	0	0	0	0	0	0	984
0	0	0	0	0	0	0	1040
350	690	0	0	0	0	0	1040
0	0	0	0	0	0	0	809
0	0	0	0	0	245	0	245
1801	1784	0	0	0	0	0	13235
0	0	0	0	1260	0	0	2545
0	0	0	0	635	0	0	1129
0	0	0	0	0	0	0	2076
966	314	0	0	0	0	0	3737
0	0	0	0	482	0	0	1480
0	0	0	0	0	0	0	1290
0	0	0	0	0	880	120	1000
0	1800	1240	1150	0	0	0	13065
0	0	0	0	0	948	0	948
1694	2050	1610	680	2175	0	800	31031
0	0	0	0	155	322	0	477
0	520	0	0	0	0	0	520
0	0	0	0	0	0	0	973
0	580	236	200	350	500	0	4276
0	0	0	0	2142	0	0	2814
0	0	280	750	35	160	370	3564
420	0	0	0	1000	2650	350	24050
0	0	0	0	0	0	0	2573
400	0	216	100	0	0	0	716

Appendix 3. Total amount of the production

Q1	Q2	Q3	Q4	Cumulative	1	2	3	4	5	6	7	8	9	10	11	12
1590	0	0	0	**2044180**	0	0	0	0	0	0	0	0	0	0	1450	1590
10133	4520	0	0	**2049048**	570	1520	2670	3552	4742	5934	7164	8423	9678	9678	9678	10133
7540	9090	0	0	**208618**	0	0	0	3010	4499	4499	4499	4499	4499	4499	4759	7540
0	2198	0	0	**208981**	0	0	0	0	0	0	0	0	0	0	0	0
1125	2108	0	0	**2124400**	0	0	0	0	0	0	0	0	0	131	1125	1125
2602	1280	0	0	**2155073**	0	0	2602	2602	2602	2602	2602	2602	2602	2602	2602	2602
0	984	0	0	**2155557**	0	0	0	0	0	0	0	0	0	0	0	0
0	1040	0	0	**2172346**	0	0	0	0	0	0	0	0	0	0	0	0
0	1040	0	0	**2178266**	0	0	0	0	0	0	0	0	0	0	0	0
809	0	0	0	**23268**	0	0	0	0	0	0	0	0	470	809	809	809
0	245	0	0	**23429**	0	0	0	0	0	0	0	0	0	0	0	0
9650	3585	0	0	**2413**	1200	1800	1800	1800	1800	3670	5470	6050	6050	6050	6310	9650
1285	1260	0	0	**265138**	0	0	0	1285	1285	1285	1285	1285	1285	1285	1285	1285
494	635	0	0	**275376**	0	0	0	494	494	494	494	494	494	494	494	494
2076	0	0	0	**275647**	0	0	0	0	410	976	976	976	976	1316	2076	2076
2457	1280	0	0	**275658**	0	0	0	0	1225	1225	2457	2457	2457	2457	2457	2457
998	482	0	0	**275688**	0	0	998	998	998	998	998	998	998	998	998	998
0	1290	0	0	**324243**	0	0	0	0	0	0	0	0	0	0	0	0
0	1000	0	0	**324515**	0	0	0	0	0	0	0	0	0	0	0	0
5960	7105	0	0	**331047**	0	1148	2348	2348	2348	2348	2460	2460	2460	3196	5375	5960
0	948	0	0	**359344**	0	0	0	0	0	0	0	0	0	0	0	0
17359	13672	0	0	**367000**	0	0	2000	3995	3995	5430	7580	12623	16509	17359	17359	17359
0	477	0	0	**367240**	0	0	0	0	0	0	0	0	0	0	0	0
0	520	0	0	**367244**	0	0	0	0	0	0	0	0	0	0	0	0
973	0	0	0	**367418**	0	0	0	0	0	0	0	0	973	973	973	973
2410	1866	0	0	**380262**	0	0	0	800	800	1200	1600	1750	2410	2410	2410	2410
672	2142	0	0	**380302**	0	0	0	0	672	672	672	672	672	672	672	672
1729	1835	0	0	**381232**	0	0	0	0	0	0	0	0	0	131	1125	1125
12050	12000	0	0	**381622**	1500	1500	1500	2050	6350	8050	8050	8050	9735	12050	12050	12050
2260	313	0	0	**384947**	3	1280	1280	1280	1280	1300	1300	1300	1300	1300	1300	2260
0	716	0	0	**386798**	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4. Cumulative amount of production and quarterly based total output per material



Appendix 5. Production outputs chart with cumulative amount production per material