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PROGRESS TOWARDS LEAN THINKING THROUGH IMPLEMENTATION OF TRADITIONAL VALUE STREAM MAPPING OF MANUFACTURING PROCESS. CASE: VILPE OY.

Master's Thesis in

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TABLE OF CONTENTS **page**

ABBREVIATIONS

ISO	International Organization for Standardization
VSM	Value Stream Mapping
WIP inventory	Work in process inventory/work in progress inventory

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

Use of Lean philosophy has resulted in many benefits for the companies, including reduced lead time, improved quality of products, greater productivity and smoother operations. Lean consists of many tools and methods which help to minimize inefficiency for example through identification and elimination of 8 types of waste. One of Lean tools called Value Stream Mapping (VSM) was applied in case company in order to discover areas for improvement of the process within VILPE Oy. The objectives of the study were to identify what wastes can be found in the company through implementation of traditional VSM and suggest methods of reduction or better control over found waste.

VSM tool can be combined with other seven mapping tools for better identification of wastes. However, as wastes in the form of transportation and motion were identified in the company before – only traditional VSM was applied in this study. In addition, future value stream map is not created, because standard improvement methods usually utilized after implementation of VSM are not used. Instead as inventories, especially end-product (finished goods) inventory, were discovered to be main waste, further analysis of inventories was performed. Analysis revealed that end-product inventory is anticipation inventory. Solutions for better control of anticipation inventory are formed based on theories of inventory management and demand forecasting. One solution suggests to use numbers forecasted through Holt-Winters model in reorder point calculation, while another solution suggests more simple way to consider seasonality in reorder point calculation. Currently reorder point is calculated based on average demand, what is not suitable for products with seasonality. Adjustments in reorder point together with improved qualitative forecasting are suggested as measures for better control over anticipation inventory.

KEYWORDS: Lean, Value Stream Mapping, waste, inventory management, reorder point, anticipation inventory, demand forecasting

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TIIVISTELMÄ

Lean – filosofian käyttö on johtanut moniin etuihin yrityksissä, kuten läpimenoajan lyhentymiseen, parantuneeseen tuotteiden laatuun, suurempaan tuottavuuteen ja sujuvampiin toimintoihin. Lean sisältää monia työkaluja ja menetelmiä, jotka auttavat vähentämään tehottomuutta esimerkiksi tunnistamalla ja poistamalla 8 hukkaa. Yhtä Lean työkaluista, nimeltään arvovirtakuvaus (VSM), käytettiin case yrityksessä prosessin kehityskohteiden löytämiseksi. Tutkielman tavoite oli tunnistaa hukat VILPE Oy:ssa käyttämällä perinteistä arvovirtakuvausta sekä ehdottaa menetelmiä tunnistetun hukan vähentämiseen tai sen parempaan hallintaan.

VSM työkalun voi yhdistää muiden seitsemän kuvaustyökalujen kanssa hukkien parempaa tunnistamista varten. Tässä tutkielmassa on kuitenkin käytetty vain perinteistä VSM-työkalua, sillä sellaiset hukat kuten kuljetus ja tarpeeton liikkuminen olivat tunnistettu yrityksessä jo aikaisemmin. Myöskään tulevaisuuden tilan VSM ei luotu, koska tavanomaisia parannusmenetelmiä, joita tavallisesti sovelletaan VSM:n käyttöönoton jälkeen, ei käytetty. Sen sijaan varastojen analysointi toteutettiin, sillä varastot, erityisesti lopputuotevarasto, olivat tunnistettu päähukaksi. Analyysin yhteydessä selvisi, että lopputuotevarasto on ennakointivarasto. Ratkaisut ennakointivaraston parempaan hallintaan perustuvat teorioihin varastonhallinnasta ja kysynnän ennustamisesta. Yhdeksi ratkaisuksi on ehdotettu Holt-Wintersin mallin kautta ennustettujen lukujen käyttöä tilauspisteen laskennassa, kun taas toinen ratkaisu perustuu helpompaan tapaan ottaa kausivaihtelu huomioon tilauspisteen laskennassa. Tällä hetkellä tilauspiste on laskettu keskimääräiseen kysyntään perustuen, mikä ei ole sopivaa tuotteille, joille kausivaihtelu on tyypillistä. Säätöä tilauspisteessä sekä parantunutta kvalitatiivista ennustetta on ehdotettu keinoiksi ennakointivaraston parempaan hallintaan.

AVAINSANAT: Lean, arvovirtakartoitus, hukka, varastonhallinta, tilauspiste, ennakointivarasto, kysynnän ennustaminen

1 INTRODUCTION AND METHODOLOGY OF THE THESIS

1.1 Background and purpose

Competition in construction business is tight. VILPE Oy is construction company for which this thesis is done, and throughout the thesis it mostly referred as the company. "*VILPE Oy was founded in 1975, in Vaasa. With years the company has expanded its range of products, currently providing top-quality products for various building and roof types, including more than 30 patented solutions. Regarding competition, VILPE Oy relies on innovative product development, in-house production, high quality, professional staff and solid partnerships (VILPE Oy:2018)."* Focus of this thesis is on high quality. By definition of ISO – "*quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs (Janakiraman&Gopal:2006)."* Needs of customers can change and differ, but what customers definitely do not need are activities in the process, which do not bring customers any value. *"Lean philosophy based on Toyota Production System (TPS) and other Japanese management practices seeks to help to identify and eliminate non-value added activities"* or in other words – wastes (Modi&Thakkar:2014).

There are 8 types of waste that can be detected: overproduction, waiting, overprocessing, transportation, excessive inventory, motion, defects and non-utilized talents. To detect the wastes in the company one of Lean tools called Value Stream Mapping (VSM) will be used. Good aspect of elimination of identified wastes is possibility to achieve reduction in lead time. Lead time refers to time which starts from the moment the customer expresses the need for the product and places the order until this requested product is actually delivered to hands of the customer (Okyere&Annan: 2015).

The main aim of the thesis is to use VSM in order to implement 2nd principle of Lean: recognize the value stream, so that the processes needed to manufacture the product are known and aimed to be improved, taking into account the end customer perspective

(Emiliani: 1998). Thus, the objective is to discover potential areas for improvements in the company and suggest reduction or better control over identified waste. Research questions and objectives of the study are summarized next.

Research questions to be answered in the study:

1. What types of waste can be identified through implementation of traditional VSM?
2. How to achieve reduction of/ better control over identified waste?

Aim: To apply Lean tool, helping the company to identify problematic areas for development.

Objectives:

1. Perform Value Stream Mapping
2. Identify wastes within production process
3. Discover on which waste there is a need to focus on
4. Suggest improvement actions for reduction/control over discovered waste

1.2 Limitation

Traditional VSM was applied in this thesis, without being added with advanced tools associated with VSM because some wastes such as transportation and motion were already discovered in the company before.

Future Value Stream Map is not performed, because standard improvement methods usually utilized after implementation of VSM were not used. Instead inventory management and demand forecasting theories were applied to investigate and eliminate discovered waste.

The study was done only for two most demanded products of the company; however, VILPE Oy has huge variety of other products. VSM is mostly suitable for high volume and low variety cases, however the company is producing in high volumes and high variety of products.

Usually reduction in lead time is achieved when WIP inventory is reduced. However, in this thesis finished product (end-product) inventory has been under consideration and solutions for its better control were suggested.

1.3 Structure of the work

Chapter 1: The chapter demonstrates background, research questions, objectives and methodology of Master's Thesis. Scientific approach, research strategy, data collection and data analysis methods as well as research methods are described. Also, this chapter tells about validity and reliability of the study.

Chapter 2: The chapter represents theoretical framework of Lean and VSM. First definition of Lean is given, including five principles of Lean as well as eight types of waste which Lean recognizes as non-value added activities. Then detailed description of VSM tool is given, including definition of the tool, its application, advanced forms, disadvantages as well as detailed instruction on how to perform VSM.

Chapter 3: This chapter shows theoretical framework of methods used in analysis and formation of solution. Knowing limitations of VSM and taking into account needs of the company, theoretical background consists of inventory management aspects such as types of inventory and inventory control system as well as description of forecasting methods and forecasting errors.

Chapter 4: This chapters shows how data for VSM was collected and analyzed. Findings observed through VSM are summarized and further discussed with representatives of the company. Based on results of discussion observed waste in the form of excessive inventory was explored further. Behavior of end-product inventory, WIP inventory as well as raw material inventory from 2012 to 2017 accompanied by behavior of sales and production are presented and analyzed.

Chapter 5: This chapter describes how improvement in forecasting methods and another possible option to consider seasonality factor of sales suggested by author of this thesis, could help to control better end-product inventory.

Chapter 6: Conclusion summarizes answers on research questions.

1.4 Methodology

1.4.1 Scientific approach and research strategy

Scientific approach

There are two scientific approaches named inductive and deductive approaches which are applied in the studies. Deductive reasoning also called "top-down" approach begins with the more general perspective and continues to the more specific. It starts with a social theory, thus the researcher studies what others have done, reads existing theories, then derives hypotheses that emerge from those theories and tests it. Inductive reasoning also called bottom up approach is opposite to deductive reasoning. Bottom up approach begins by collecting data, and then observation of pattern takes place so that theory can be derived from this pattern. In other words, inductive approach moves from data to theory, or from the specific to the general (Saylor Academy Open Textbooks: 2012). This thesis follows mostly inductive approach, as first data is collected, and then observed what data tells about what types of waste can be found with traditional VSM. Thus, there is no hypothesis which seeks for acceptance or rejection as deductive approach suggests, even so thesis starts first with theory on VSM. Patterns of both scientific approaches are presented in Figure 1.

Figure 1.Inductive and deductive research (Russell:2015).

Research strategy

Research strategy of this thesis is case study due to the fact that the thesis follows criteria of case study defined by Yin (1994). According to criteria, investigator does not control events, under investigation is present time phenomena and research questions are usually “how”, “why” and sometimes “what”.

Case studies can be single or multiple. As this thesis is done for the company and limited to one organization – this is single case study. There are three types of case study: exploratory, descriptive and explanatory:

Exploratory. Exploratory research can also be called preliminary research. The aim is to get familiar with investigated topic in order to achieve better understanding of the studied situation. In exploratory research, researcher is not sure yet what is the scope and what is actual problem of the study (Sebunje:2015).

Descriptive. Descriptive research is deeper than exploratory research. In descriptive research problem is identified, data which is usually quantitative is collected, and analyzed by statistical techniques. However, in descriptive research causes or reasons on specific behavior are not presented (Sebunje:2015).

Explanatory. This type of study serves as nest step of descriptive research. The researcher searches for the reasons, aiming to explain situation outlined in descriptive study (Sebunje:2015).

Firstly, the thesis reminds characteristics of exploratory case study. It starts with “what” question, aiming to explore what kind of wastes can be detected by utilizing traditional VSM. There is no statement of hypotheses. Initial research is conducted which is followed by further studies after wastes were observed.

Next, the aim is to describe situation on inventory, using statistical techniques for analysis, and explain why it is excessive, suggesting ways of improvements. Consequently, study has combined characteristics of descriptive and explanatory case studies too. Thus, the research strategy of this thesis is single case study, which first takes the form of exploratory study and followed by combination of descriptive and explanatory study.

Case studies are usually associated with qualitative research method, however, studies can be based a mix of quantitative and qualitative methods, what is true in this thesis, where mix method is applied (Yin:1994).

1.4.2 Methods of data collection and data analysis

Methods of data collection

Collection of data is divided into two approaches: primary and secondary source of information. Primary source means that research collects raw data while secondary source is already collected and processed information. These approaches are further divided into following data collection methods: documents, observations, interview, and questionnaire (Kumar: 2011). Data collection methods are presented in Figure 2 below.

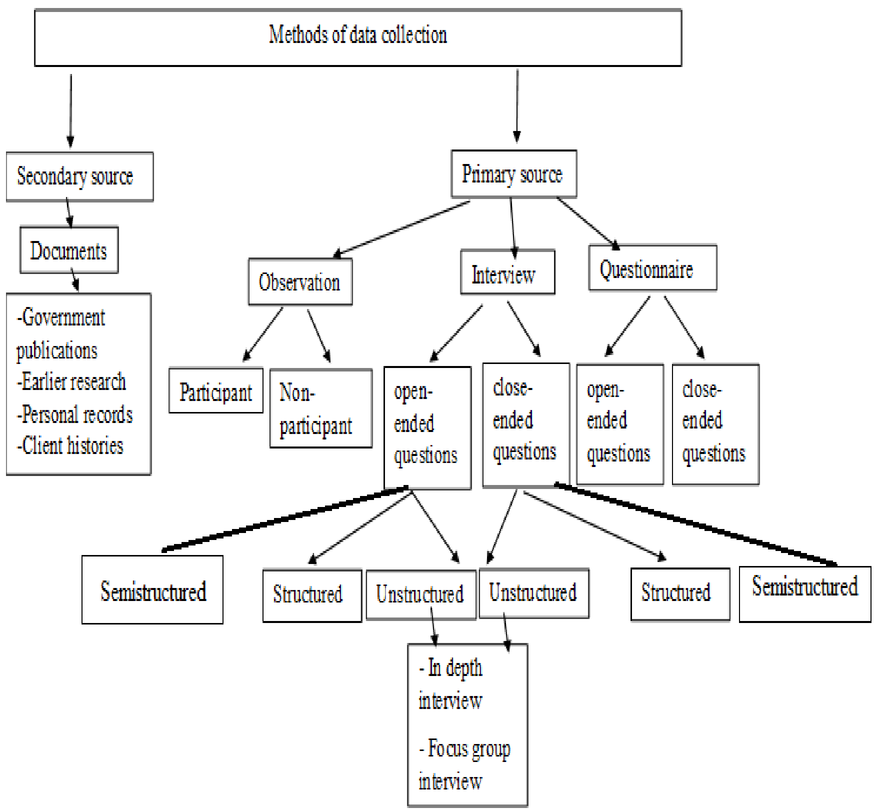

Figure 2. Data collection methods. Adapted and modified from Kumar (2011).

In this thesis structured interview with open-ended questions, questionnaire with open-ended questions, focus group interview with open-ended questions as well as earlier report done for the company before (internal document of VILPE Oy: 2015) were applied.

To collect data needed for implementation of standard VSM, structured interview with open-ended questions was conducted to quality engineer. For example, researcher asked to name the most demanded products and to describe the process of production of the most demanded products. In addition, open-ended questions were sent by e-mail to quality engineer. Open-ended questions were answered by sending files with numerical data. Data was extracted from QlikView - Business Intelligence platform.

Focus group interview were applied to discover on which of identified wastes, researcher has to concentrate further. According to Kumar (2011) focus group interview is conducted with people who are working in same area and have knowledge about the topic. Thus, researcher conducted interview together with quality engineer, factory supervisor and product/production development engineer. Interview led to further study of waste in the form of inventory.

To conduct further study on behavior of inventory, quality engineer was sent by e-mail open-ended questions, asking to send numerical data, for example on amount of inventory, sales and production of products selected for VSM as well as their components and inventory monthly from years 2012 – 2017. Sent data was also found in QlikView. Further, structured interviews with open –ended questions were conducted to factory supervisor and product/production development engineer in order to discover the reasons for high level of inventories in 2012 and 2017, as well as to production planner to discover how reorder point is calculated.

Methods of data analysis

Descriptive statistics was used to analyze data. Descriptive statistics is quantitative analysis used to represent data. It contains measures of central tendency such as mode, median, mean; graphical methods and measures of dispersion (Research Connections:2018). For example, average demand of two selected products for years 2016 and 2017 as well as their set up and cycle times were calculated. Also set up time, cycle time and lot size information were presented through bar graphs. Inventory and production level are also presented through bar graphs.

In solution part, time series analysis was used to show that current naïve forecast does not work and utilization of better forecasting method can help to achieve better control of inventory. Time-series analysis makes it possible to derive decisions based on time related changes of phenomena or to forecast quantity of future phenomena (University of Jyväskylä:2010).

1.4.3 Research methods

As was mentioned case study can be as qualitative as quantitative what applies also in this study which has features of both research methods. Qualitative study is basically associated with data expressed in words while qualitative data is about processing numeric data, however it is not that straightforward.

The research method of this thesis is mix method which takes characteristics of both research methods. Beginning of the study remains more of qualitative method, because according to ACAPS (2012), qualitative method is used when expert is aware of the topic to be explored only approximately. Before the waste in form of inventory was identified, the need to work at was unknown. In addition, study does not seek to confirm hypotheses instead, first the aim is to explore what types of waste can be deducted using standard VSM. However, collected data is of both types as of qualitative, because of received comments in verbal form related to continue of the study after VSM implementation as well as received comments on behaviour of inventory; as of quantitative, because most of data is received in numerical form. In addition, data collection methods of both types were used as data was collected through focus group interview as well as structured interview. Data analysis is more of quantitative nature as descriptive statistics together with time series analysis is used to process data.

1.4.4 Validity and reliability

Validity means that research measures what was aimed to measure. Validity consist of construct validity, internal validity and external validity.

Construct validity: establishing accurate functional procedures for the studied topic (Yin:1994).

Internal validity: establishing the right logic of results and basically used in explanatory study (Yin:1994).

External validity: establishing the ability of the study to be generalized and used in similar cases (Yin:1994).

Reliability of the study means that another researcher should be able to get the same results while repeating the same study, in the same company.

Construct validity of this thesis was gained by having multiple sources of evidence. Information was gained as by processing numerical data as by verbal response. Internal validity was achieved by gaining explanations on if excessive inventory truly takes place and why. The same questions were asked from quality engineer, factory supervisor, product/production development engineer and production planner during focus group interview as well as individually at different time, and all of them gave the same answer, which explains well situation presented by graphs. In research design to provide external validity, theory was used. For example, based on Lambert&Abdul-Nour (2012) VSM is suitable tool for implementation in SME. Case company belongs to SME.

Reliability of the study must be good. Collected data in numeric form comes from data base, consequently another researcher can extract the same data. Confirmation on right interpretation of the data was asked from representatives of the company. Logic of data analysis and how data was analysed is documented throughout the thesis.

2 LEAN AND VSM

2.1 Lean

Lean manufacturing is a method used in the production of quality goods aiming to facilitate production at a lower cost, lesser time, and lesser effort. This philosophy promotes the use of less manufacturing space, human effort, and lesser investment in inventory, tools and engineering time. Lean manufacturing is based on the Toyota Production System (TPS) together with practices of Japanese management that seek to eliminate waste in production what allow to make time between customer ordering and final product shipment shorter. Modi and Thakkar (2014) further noted that lean manufacturing identifies and eliminates wastes in various business aspects and therefore enriches customer value.

2.1.1 Five Lean principles

The philosophy of lean manufacturing has foundation in five main principles. These are: specify value, identify the value stream, flow, pull, and perfection as described in the following paragraphs.

Specify value. In a lean production system, the end consumer is responsible for defining the product value. This is because the needs of the customer must be met by the product at both time and price (Emiliani:1998).

Identify the value stream. This means understanding all the activities necessary for the production of a specific product with the optimization of the whole process from the customer perspective. The customer input is very significant because it helps in the identification of activities that add value, activities that add no value but can be avoided, and activities that add no value but cannot be avoided (Emiliani:1998).

Flow. After the specification of value and identification of value streams were done, the next step is obtaining activities that add value to the flow without any interruptions. In lean production the term “flow” means the continuous processing of parts right from raw materials to finished goods, and one operation or one piece at a time. This is different to batch and queue manufacturing where there is sequential processing of large batches; that is, all parts have to be processed by the prior operation before the entire batch move to the next operation. This is a discontinuous method of production that leads to lengthy queue time and huge quantities of expensive inventory that cumulatively increase the price of the final product. However, Emiliani (1998) noted that batch production method as well as queue production method are still more influential because many benefits of flow are questionable.

Pull. After elimination of wastes and setting of the flow, the inner customer (worker of previous process) is allowed to pull their product or services through the process (Nave:2002). In lean production, the pull concept means responding to the pull or demand of the customer. In lean processes, operations are designed with the never stable requirements of the final customer in mind. This is different from batch and queue manufacturing in which the design of the process is done to meet the local needs (Emiliani:1998).

Perfection. In lean manufacturing, perfection implies the continuous improvement of all forms of resources used in production. With the regular elimination of waste, the cost of operation is reduced and therefore the desire of end-use customers for the greatest value at minimum price is fulfilled (Emiliani:1998).

Figure 3. 5 Principles of Lean (The Lean Enterprise Institute:2006).

2.1.2 Eight types of waste

The idea behind lean manufacturing is to create value that customers have will of being paid for and to minimise waste (non-value adding) activities that customers cannot afford. Originally there have been 7 types of waste, however in year 2004, 8th type of waste was added. Types of wastes are summarized below.

Overproduction. Overproduction means creating more than the demand or producing early before the need arises. Overproduction is associated with various consequences which include high risk of producing wrong items, risk of obsolescence, and huge possibility of selling the overproduced items at a lower, discounted prices or even throw them away as rubbish. However, in some situations, it is necessary to have an extra supply of finished or semi-finished products even for lean manufactures (Chennakesava: 2009). The rationale for overproduction may be the prediction of the number of defects, equipment not working or employees not being present at working place (Grzelczak & Werner-Lewandowska: 2016).

Waiting. Waiting occurs when operators or equipment are idle and have to wait for tools, raw materials or the maintenance team (Quesada & Buehlmann: 2011). Small delay in units processing is also considered to be wastage. With waiting the cost of labor and depreciation cost per unit of output rise (Chennakesava: 2009).

Unnecessary transportation. The unnecessary transportation of parts, information or goods is a wastage (Quesada & Buehlmann: 2011). Unnecessary transportation can occur when the distance between the various stages of production are long. The long distances entail material, WIP and finished goods movement using different transport and this is associated with loss of time, generates additional costs as well as the possibility of the goods being damaged during transportation (Grzelczak&Werner-Lewandowska:2016).

Overprocessing or incorrect processing. Refers to processing of products more than the customer requirements in terms of quality or additional features (Chennakesava: 2009). Incorrect processing on the other hand arises due to incorrect technology selection and/or incorrect layout of the production line. Overprocessing and incorrect processing consumes more time in order to create one particular product (Grzelczak&Werner-Lewandowska: 2016).

Excess inventories. There is a close relationship between overproduction and surplus inventories (Grzelczak&Werner-Lewandowska: 2016). Excess inventories can be due to excess raw materials, WIP or finished goods and result in obsolescence, not needed transportation, long waiting times, defaced products, holding and production costs (Quesada&Buehlmann:2011).

Motion. This refers to unwanted motion by employees associated with long walking distances and searching for tools or parts (Quesada&Buehlmann: 2011). Inappropriate organization of the workplace is the main cause of needless movements (Chennakesava: 2009).

Defective products. Entails the production of products that do not meet customer requirements leading to unhappy customer and rising manufacturing costs (Quesada&Buehlmann: 2011). Besides the physical defects, errors in paperwork may also be classified as defects in production as well as late delivery, incorrect product information, use of more than enough raw materials, production to wrong specifications or production of unwanted scrap (Grzelczak&Werner-Lewandowska:2016).

Non-utilized talent. Occurs when employees are not adequately involved in their work. This cause the loss of ideas, time, competences, and possibilities for learning and improvement (Quesada&Buehlmann: 2011).

2.2 Value Stream Mapping (VSM)

VSM is a Lean philosophy associated tool that is utilized in the visualization of the flow of the raw materials as well as information in a process as the product moves from one stage to another. Womack and Jones (2008:1) noted that VSM allows the direct observation of materials and information flow as they occur using visual summaries, representing a future state with much more improved output. According to Womack and Jones (2008:1): "*VSM allows the visualization of station cycle times, buffers of inventories at intermediate stations, deployment of manpower, uptime, resource utilization, and the flow of information in a selected area*." Additionally, VSM makes it possible to capture the entire processing cycle right from raw materials to the finished goods. VSM puts into consideration both value-added and non-value-added activities (Seth&Gupta 2005). The main aim of VSM is waste identification in the value stream and its elimination (Rother&Shook 2003:4) due to its ability to see the source of waste in a process.

Four stages are followed in VSM. These are:

1. Product family selection
2. Current state map construction
3. Future state map establishment
4. Future state map implementation

2.2.1 Material and information flow

Material flow includes every step which materials undergo to be transformed in the form of the end product which customers acquire. Besides material flow, there is also information flow which is considered to be harder to map. Information flow tells each process its task and illustrates the following aspects:

- communication from the customer to the production control, representing the customer´s forecasts and orders
- communication from production control to supplier, representing production control's monthly forecast and weekly orders
- communication between production control and production supervisor
- communication between production supervisor and the appropriate individual process (Tapping, Luyster&Shuker 2002:87).

2.2.2 Application of VSM

VSM is applied in large companies to strengthen their lean thinking. However, numerous studies conducted in small and medium-sized enterprises (SME) proved that VSM is also suitable there.

Broad study was held by Lambert&Abdul-Nour (2012) who during 15-years period compared which of two different process mapping methods JIT Characterization or Value Stream Mapping are more helpful for SME in achievement of world class manufacturing. The study was implemented in 95 SME from different sectors including metal processing, electronics, rubbers, plastics, composites, woods, etc. Results showed that these two methods process the same problem related to productivity as well as obtain identical results on operational situation. Authors concluded that VSM method is a good enough for SME and in addition it takes less time to complete in comparison with another method.

Example of more specific study conducted by Narke&Jayadeva (2016) is focused on one small pump manufacturing company. VSM helped the company to visualize the process and detect the waste in form of internal transportation and inventory. Future actions taken to reduce waste helped the company to reduce lead time by 3%.

VSM is a good tool as for large companies as for SME, however if VSM is suitable for production process depends on certain situation. Quarterman &Snyder (2006:48) introduced the table describing situations on production level which are mostly or less suitable for being mapped through VSM.

Table 1. Application of VSM (Quarterman &Snyder 2006:48).

Use of VSM		
	Suitable	Not suitable
Volume	volumes are high	low volume is a problem
Variety	variety must be low	variety is high
Equipment	equipment is dedicated	multiple equipment shared
Routings	routings are simple	routings are complex
Components	several	a lot of parts and sub-assemblies
Strategy	Toyota Production System	Non-Toyota System

VILPE Oy can be considered as suitable candidate for implementation of VSM based on information on application of VSM described above. The company is medium sized company. It produces in high volumes, however in high variety of products. Products follow simple routing with relatively few components. Moreover, case company is entering the way of continuous improvement being oriented to the Toyota version of Lean Manufacturing.

2.2.3 Advanced VSM

VSM is used for mapping broad picture of whole organization. However, if detailed analysis on gaps is needed across the whole supply chain, VSM can be combined with other seven mapping tools: Process Activity Mapping, Supply Chain Response Matrix, Production Variety Funnel, Quality Filter Mapping, Demand Amplification Mapping, Value Analysis Time Profile and Decision Point Analysis (Hines & Rich 1997). Each of the mapping tool is useful in identification of certain waste across supply chain. Table 2 demonstrates summary of the seven mapping tools outlining their definition, application and usefulness in detection of certain waste. Seven types of waste out of eight types are demonstrated in Table 2, as 8th waste in the form of non-utilized talent was suggested later in 2004.

Table 2. Seven mapping tools with their definition, application and usefulness in detection of seven types of waste (Hines & Rich 1997; Hines & Taylor 2000).

	Process activity mapping	***Supply chain response matrix***	***Production variety funnel***	***Quality filter mapping***	***Demand amplification mapping***	***Value analysis time profile***	***Decision Point Analysis***
Definition	Mapping of order fulfilment process is done in details	Lead times and inventory assessment is done	In every step of manufacturing process all variants of products are shown	In supply chain or in the order process quality problems are identified	The demand amplification map is a graph of quantity against time	Mapping activities considering in Cost-Time Profiles	Shows where in a supply chain exist an expected level of buffer stock
Application	For identification of productivity possibilities and lead time within whole supply chain for physical product flows as wells as information flows	For identification of inventory and significant sectors of time Makes possible to evaluate the necessity to keep stocks within the short lead time replenishments.	For identification of inventory by combining short lead time with plant flexibility. Useful in determining opportunities for postponement; Useful to highlight bottleneck areas of design.	For demonstration of place for location of three types of quality defects including (Scrap defects, Product defects and Service defects) by integrating quality and logistics performance measures	Known as ‘bullwhip effect’ or ‘Forrester effect’; To explore batch sizing policies and scheduling together with inventory decisions.	To show storage of value adding and non-value adding costs against time	To determine where the products’ flow in the value stream goes from push system to pull system.

Overproduction	maybe	maybe	no	maybe	maybe	yes	maybe
Waiting	yes	yes	maybe	no	maybe	maybe	maybe
Excessive transportation	yes	no	no	no	no	maybe	no
Inappropriate Processing	yes	no	maybe	maybe	no	maybe	maybe
Unnecessary Inventory	maybe	yes	maybe	no	yes	maybe	maybe
Unnecessary motions	yes	maybe	no	no	no	no	no
Defects	maybe	no	no	yes	no	maybe	no

Table 3 suggests that combination of VSM and Process Activity Mapping can help to detect almost all types of waste. Process Activity Mapping is particularly good in detection of waiting, transportation, overprocessing and motion. However, in previously conducted study in case company: transportation, waiting and motion wastes were detected. Consequently, the author of this thesis will apply only VSM without combination with any of other seven mapping tools.

2.2.4 Disadvantages of VSM

VSM has its disadvantages, which are important to keep in mind while using the tool. Some limitations of VSM outlined by Khalid, Hashim, Salleh (2014) and Kwasala, Shahrukh (2001) and are relevant for this study:

1. Using the manual VSM model only allows the generation of a static model which possesses challenges in monitoring and assessment of processes of the map. An optimistic performance evaluation will be attained using this tool. Static analysis will also produce more mistakes if the system has greater variability. Moreover, while using the VSM model, the user only gets ”*a snapshot of the situation on the shop floor at one specific moment*” (Khalid, Hashim, & Salleh: 2014).

2. VSM is also prejudiced in that it favours the use of continuous flow, kanban based pull scheduling, assembly line layouts etc that are not appropriate for high volume and low variety (HVLV) manufacturing systems (Kwasala&Shahrukh: 2001).

3. Does not have any good economic measure for “value” such as operating costs, throughput, profit or inventory expenses (Kwasala&Shahrukh: 2001).

4. Does not demonstrated the impact of WIP, throughput of the orders and the operating expenses of the inefficient flow of materials in a production setting (Kwasala&Shahrukh: 2001).

2.2.5 Structure of VSM

2.2.5.1 Selection of a product family

To implement the VSM model, the first step is the identification of a product family or a single product. A product family is that which go through similar steps in processing and in downstream processes go over common equipment (Rother & Shook 2003: 6). There may be variation in the products in terms of size, color or a difference in one or two production steps. However, complication can arise in the choice of the product – if this occurs Part Quantity Process Routing (PQPR) Analysis can be used (Nielsen 2008: 3).

Part Quantity Analysis

PQ analysis is useful in displaying the product mix as a Pareto chart. A Pareto chart provides a graphical representation of the Pareto principle which is also alternatively known as the 20:80 rule. The chart helps in the separation of the “critical few” from the “trivial many” (Tapping, Luyster&Shuker 2002: 28-30).

1. Obtain 3 to 6 months’ worth of data on production output.
2. Enter your products by quantity (from greatest to least) on a PQ analysis list.
3. Create a Pareto chart based on obtained data.

4. Analyze the product mix.

If a 40:60 ratio is obtained from the PQ analysis it is an indication that there is a high variety of products that have a small volume of each type. This means that more analysis should be conducted (Tapping, Luyster&Shuker 2002: 28-30).

Process Routing Analysis

PR analysis helps to show which products or parts have similar process routes.

1. Start by showing the sequence of operations for each product type listed by volume.
2. Combine together the products that have similar routings in the process (Tapping, Luyster&Shuker 2002: 28-30).

Table 3. Part Quantity Process Routing (PQPR) Analysis (Nielsen 2008: 3).

Quantity			Process							
Part#	Demand	% of total	A	B	C	D	E	F	G	H
1	420	35%	X	X	X		X		X	X
7	288	24%	X	X	X		X		X	X
3	276	23%	X	X	X		X		X	X
9	84	7%	X		X	X	X	X	X	X
2	48	4%	X		X	X	X		X	X
6	24	2%	X		X	X	X		X	X
5	24	2%	X		X	X	X		X	X
8	12	1%	X		X	X	X		X	X
4	12	1%	X		X	X	X		X	X
10	12	1%	X		X	X	X		X	X

PRODUCT FAMILY

SORT BY DEMAND

2.2.5.2 Construction of a current state map

Construction of current map starts with collection of data. Steps of implementation of current state map are outlined below. They were collected based on guidelines of authors: Tapping, Luyster&Shuker 2002: 84-91; Quarterman &Snyder 2006: 53-64; Rother&Shook 2003: 18-

38; Gåsvaer 2014; O'Connor&Hamel: 2017; Kumar, Shivashankar&Rajeshwar: 2015; Langstrand: 2016.

1. Draw icons representing the customer, supplier and production control (Rother&Shook 2003: 18).
    - Use the same icon to represent the customer and the supplier.
    - In the upper right corner of the sheet, draw the customer icon.
    - In the upper left corner draw the supplier icon.
    - Draw the production control icon between the customer and supplier icons.

2. Below the customer icon, draw the data box and enter the customer requirements in it. The daily and monthly requirements of each product should be included in the box. The frequency and size of the batches should be indicated if the customer orders in infrequent batches (Rother&Shook 2003: 19).

3. Then, the icons for inbound and outbound shipping should be drawn as well as the truck and delivery frequency. Partial, full or mixed loads should be noted (Quarterman &Snyder 2006: 53).

4. Begin from left to right, sequentially draw boxes for each of the processes. The process box is used to indicate a process in which there is the material flow (Quarterman &Snyder 2006: 53). A process is different from a department or a function. For parallel flows, draw them above each other. When a process is disconnected the process box should stop as well as the flow of the material. For this reason, one should leave enough space between each of the boxes. During the processing, if the material is stored at one point or stands idle between process, this should be noted in the form of WIP and its amount noted (Gåsvaer: 2014).

5. Add data boxes below the process boxes (Quarterman &Snyder 2006: 61).

Table 4. Data box suggested information (Quarterman & Snyder 2006: 61).

Item	***Description***
Cycle time C/T	The time needed to manufacture one piece of product and to begin manufacturing of the next piece
Changeover time C/O	The time required to produce final piece of one product and getting first unit in good condition of following product
Availability time	All time during the day when workstation is accessible for changeover or production of the mapped product family
Uptime%	Available time expressed in average percentage that indicates the actual time when workstation is operating excluding effects of breakdowns and maintenance
Scrap Rate	Defective product amount that needed to be scrapped or reworked shown in average percentage
Number of people	Required number of people in order to handle the process, which is presented with operator icon as shown inside the process boxes

Cycle time can be measured either as machine cycle time if process is machine-intensive and requires little or no human intervention or as operator cycle time if process is performed manually. In addition, cycle time and processing (process) time usually are considered to be the same, however there is a difference as processing time means elapsed time during which a product is being worked on, whether the work is value added or not, within a given work station (O'Connor&Hamel: 2017). In this thesis, in VSM definition of cycle time is used instead of processing time. Cycle time is either measured by performance of machine or human depending on the process. Summary on time meanings applied in VSM is presented in Figure 4 and Figure 5.

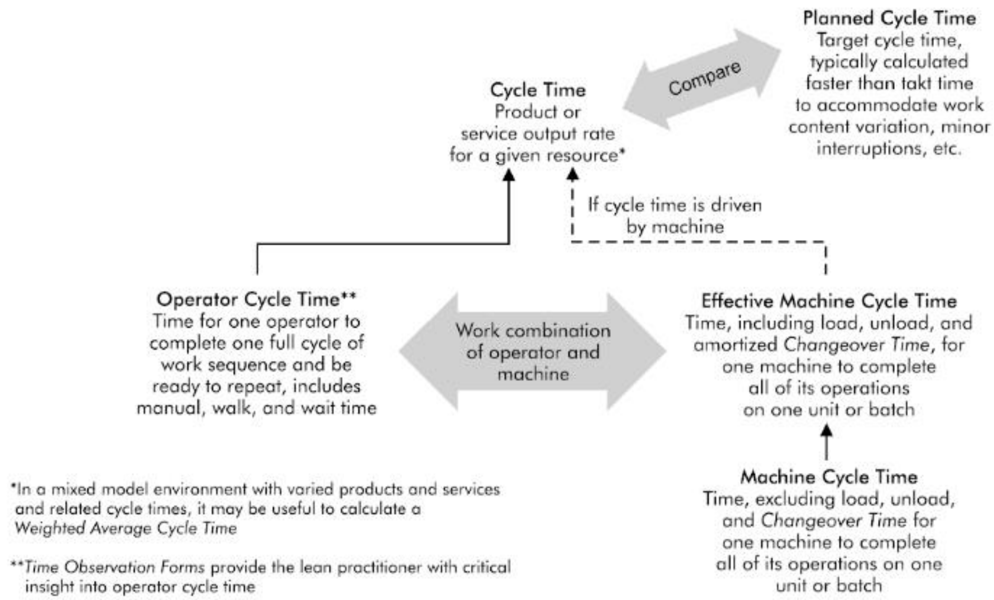

Figure 4. Cycle time overview (O'Connor&Hamel: 2017).

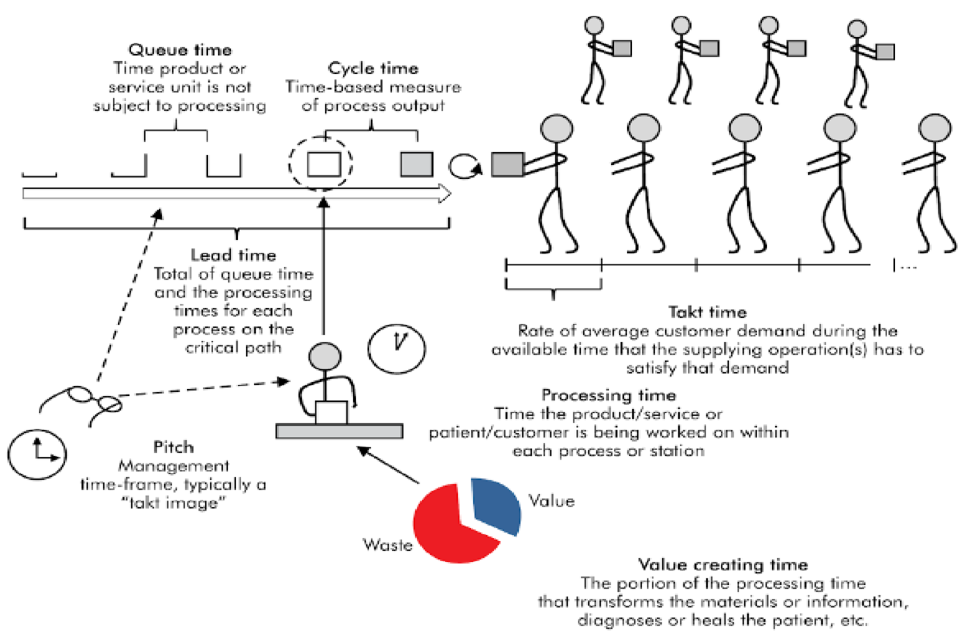

Figure 5. Time overview (O'Connor&Hamel 2017).

Sometimes changeover time and set up time are considered to mean the same. However, there is a difference as changeovers are a subset of setups what can be seen in Figure 6. In this thesis changeover time represents time of changing one raw material to another one while setup time is a time needed for getting machine ready to produce new detail including change of mold. Consequently, instead of changeover time in VSM will be shown setup time.

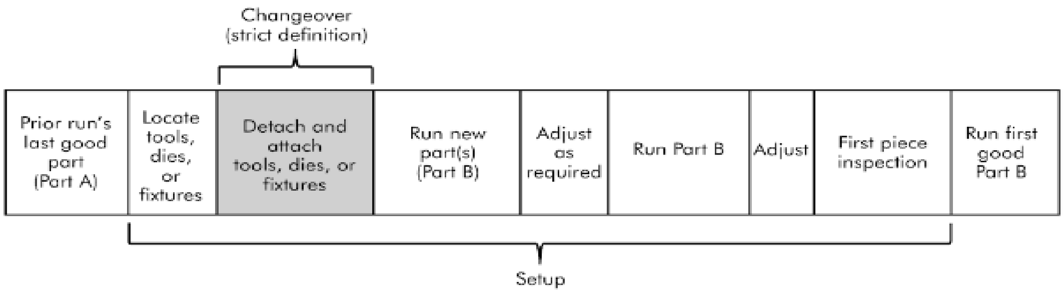

Figure 6. Changeover and setup time (O'Connor&Hamel 2017).

6. Add inventory locations and levels in production units. All inventory has to be interpreted as equivalent quantity of finished goods (Quarterman &Snyder 2006: 58). To calculate inventory lead time - average inventory at each location is divided by the daily customer requirement. Inventory can consist of many different details, components and sub-components, therefore the most significant once can be chosen for VSM. In this thesis, each inventory is observed by discovering reorder points of each significant unit within particular inventory and conducting average of reorder points.

7. The next step is showing the timeline in the form of value added time and non-value added time. Value added time are those actions that increase significance of a product throughout raw material processing to semi-finished products and finally to finished products. On the other hand, non-value added time is waste (MUDA) and may be associated with time wastage and collection of WIP products. Usually, accumulated inventory equals inventory time while cycle time equals value-added time. Some of the non-value adding (NNVA) time are necessary in some circumstances and this

includes walking to collect parts, unpacking or moving deliveries (Kumar, Shivashankar&Rajeshwar: 2015).

8. Next, push, pull and FIFO icons are added. Push system refer to the usual inventory management and timing such as MRP. In push systems, a schedule is sent to all process and the process is expected to initiate attempt to work on the schedule. In case a process experiences any form of problem, this is not relayed to other processes downstream or upstream and therefore the processes keep working following the original schedule. Huge inventories between processes are needed for variances between the timed activity and their in-fact implementation (Tapping, Luyster&Shuker 2002: 84).

   On the other hand, the pull system holds a small amount of inventory for every job between processes in Kanban stockpoints (or Supermarkets). This allows the downstream process to take what is needed with the upstream process filling in the gaps (Quarterman &Snyder 2006: 63).

   In FIFO systems, parts are transferred by the upstream process to the downstream process in sequences. The part that arrives next is worked on by the downstream process next (Quarterman &Snyder 2006: 64).

9. Calculate total cycle time and lead time. Lead time is achieved by calculating the sum of value added and non - value added times (Quarterman &Snyder 2006: 64). Various icons are used in illustration of VSM. Process icons, material icons, information icons and miscellaneous icons are summarized in Appendix II.

10. Analyze VSM. First step is to perform comparison between takt time and cycle times. If happens to be that cycle time of certain process is higher than takt time, customer demand can not be satisfied due to fail in supply of required amount of products. The

second step is to perform comparison of cycle times between operations, what is needed to be done by several reasons. The first and the most important reason is that it is needed for identification of potential bottlenecks in the process. The second reason is that in this case it is possible to implement assessment and rebalancing of the process. Uneven distribution of cycle times between operations leads to bad utilization of resources, which is costly and unproductive (Langstrand 2016). The third step could be investigation of lot sizes and setup times.

2.2.5.3 Construction of a future state map

After implementation of analysis on current state map, areas of improvements can be identified. There are basic principles and methods which are usually applied in creation of future VSM. These methods are shortly summarized below based on guidelines of Rother&Shook (2003); Nicoletti (2018) and Lee, Padmanabhan &Whang (1997):

1. *Continuous flow*. It should be executed wherever it is possible. Instead of using batches, ensure the flow of products one unit at a time (Nicoletti: 2018).

2. *Supermarkets.* This should be considered if batching is necessary and continuous flow cannot be achieved. Supermarket involves linking downstream process to upstream process that need to be implemented in batches. Once enough products have been taken from the supermarket, batch production is started as a signal is transmitted upstream. The signal may be transmitted as Kanban cards directing upstream processes to reorder or create products to restock the supermarket. This limits the total WIP, combining production closely with actual customer demand (Rother&Shook: 2003).

3. *Schedule production at one step only*. Given that continuous flow or supermarkets unite well all the processes, production scheduling is necessary be done at one

specific step only. This is referred to as the pacemaker process as it provides the directive on the pace of upstream processes (Rother&Shook: 2003).

4. *Level the production mix*. Within the same flow, multiple types of products may be produced. In such case, it is important that production of the types of products is mixed as much as possible. For example, if the same line is used to produce products A and B, one may seem attractive to produce a batch of product A during one week and a batch of product B in the next week to reduce time of changeovers. However, the downside of this is that it may cause higher levels of work in progress and higher end - product inventories. Besides it also results in unleveled demand which in turn generates a Forrester effect/bullwhip effect that results in higher demand fluctuation through the entire supply chain (Lee, Padmanabhan &Whang: 1997). Therefore, instead of implementing production consisted of the sequence AAAAAAAAAABBBBB, leveling should be used to make sequence to become AABAABAABAABAA (Nicoletti: 2018).

5. *Level production volume.* This entails releasing known volume of work into the production department. It makes possible for the department to develop an understanding of whether they are frequently on schedule or not and if there is need for any intervention (Nicoletti: 2018).

6. *Shorten changeover time.* By reducing the changeover time, it is possible to minimize the size of the batch and this allows the improvement of stability as well as achievement of leveled production (Rother&Shook: 2003).

In this thesis, traditional principles and methods of creation of future VSM outlined above are not going to be applied. That is because according to Khalid, Hashim, Salleh (2014) and Kwasala, Shahrukh (2001) limitation of VSM is forcing to apply traditional principles and methods mentioned above, however they are suitable only for high volume and low variety (HVLV) manufacturing systems, while VILPE Oy is high volume and high variety system. Consequently, in the study, aspects related to inventory management such as improved inventory control system in the form of reorder point, and better forecasting methods will serve as methods to eliminate found waste in current VSM. The methods are described in next chapter.

3 INVENTORY MANAGEMENT AND FORECASTING METHODS

3.1 Inventory management

3.1.1 Importance of inventory management

All types of businesses have some inventory which is vital as for supply chains as well as for workers. The everyday operations of an organization are affected by inventories because they must be enumerated, paid for, and utilized in organizational functions to meet the needs of the customers. For this reason, funds must be invested in inventories. Funds invested in inventories cannot be used for any other investment and therefore act as a form of outflow on organizational cash flow. However, companies understand that products' availability is crucial point in many markets as it is important for maintaining a high service level. Having huge inventory on one hand reduces the profitability of the organization. On the other hand, having too little inventory creates product shortages that harm the confidence of the customer in the organization. Therefore, trade-offs are part of inventory management (Krajewski, Ritzman, Malhotra: 2013).

3.1.2 Types of Inventory

Raw materials are the type of inventory that is utilized in the creation of goods or services. Raw materials are inputs to the product transformation process that an organization does. **Work-in-process/work-in-progress (WIP)** comprises of items that are needed for the production of the final product and may include components or assemblies. Service operations also have some form of WIP and may include for example restaurants, repaid shops, package/parcel delivery services. **Finished goods (FG)**, on the other hand, are items that are ready to be sold to the final consumer. FG may be stored in warehouses, manufacturing plants or retail outlets (Krajewski, Ritzman, Malhotra: 2013).

Inventories may also be classified on how they are created. Using this classification, inventories are classified into four main forms: cycle inventory, safety stock, anticipation inventory and pipeline inventory (Krajewski, Ritzman, Malhotra: 2013).

Cycle Inventory. This refers to the portion of total inventory with direct variation with the lot size. The determination of the frequency of placing orders and in what quantity is referred to as lot sizing. In lot sizing, two principles are applicable.

1. There is direct variation between lot size Q and elapsed time (or cycle) between orders. If an order for a given lot is done after 5 weeks, then the average size of the lot must be equivalent to the demand of 5 weeks.

2. The cycle of inventory is determined by the time between orders. Longer time is associated with greater cycle inventory. At the start of the interval, the cycle inventory is at Q, the maximum. At the end of the interval, just before the arrival of the new lot, the cycle inventory drops to the manual point or 0 (Krajewski, Ritzman, Malhotra: 2013).

The average of these two values, Q and 0, becomes the average cycle inventory.

$$\text{Average cycle inventory} = \frac{Q + 0}{2} = \frac{Q}{2}$$

This formula applies accurately when the rate of demand is invariable and uniform. However, even in cases where the demand varies, it gives a good estimate. When this easy formula is used, aspects other than the rate of demand such as scrap may generate estimation errors (Krajewski, Ritzman, Malhotra: 2013).

The reduction in cycle inventory can only be achieved through the reduction of the size of the lot that moves in the supply chain. However, reductions in Q have to be accompanied by changes in other areas, otherwise, it can be very challenging. For example, it can lead to a rise in cost of ordering or setup costs.

Safety Stock Inventory. Companies have safety stock inventories aimed to avoid the hidden costs of unavailable components and consequently service problems with customers. As such, safety stock inventory can be defined as the surplus inventory that an organization maintains to protect itself from various uncertainties in demand, changes in supply, and lead time. Safety stocks are important and help to cushion an organization against failure of suppliers to deliver items of desired quantity on an agreed date or make a delivery that does not meet the desired quality. Additionally, safety stocks also cushion an organization against undesirable situations when a significant amount of scrap is generated during manufacturing. Safety stocks ensures firms operations are not disrupted due to occurrence of these problems by allowing the operations of the organization to go on (Krajewski, Ritzman, Malhotra: 2013).

To reduce safety stock inventory, the primary lever would be to make orders when they are about to be received. However, ordering near the data of collection can be associated with poor customer services unless uncertainties associated with demand, supply and delivery can be reduced. In this case, four secondary levers can be applied:

1. Improvement in demand forecasting. This will reduce customer surprises. Increase customer collaborations. This will allow receiving of advanced warning to facilitate changes in the levels of demand.

2. Reduce the lead times for produced as well as purchased items to minimize demand uncertainty. Look at the possibility of using local suppliers.

3. Reduce uncertainties related to suppliers. Measures to achieve this is by sharing production plans with suppliers and collaborate more. Improving manufacturing processes can also educe scrap and/or reworking. Downtime caused by failure of equipment can also be reduced by initiating preventive maintenance.

4. Improve reliance on labor and equipment buffers such as cross-trained workers and capacity cushions (Krajewski, Ritzman, Malhotra: 2013).

Anticipation Inventory. Refers to the type of inventory that is used to cushion against uneven rates of supply or demand. Anticipation inventory is useful in seasonal demand situations. A manufacturer can be eager to reserve anticipation inventory by uneven demand levels during low demand periods so that the levels of output do not have to be raised when the demand goes up again. Using this approach, laying off workers during low demand seasons is avoided as well as the cost of hiring additional workers or substitutional workers in place of permanent workers who are on holidays during summer when demand is up. Because of the use of this process the business can have a steady output and a stable workforce. Furthermore, the benefits of anticipation inventory also exist when suppliers may be facing strike threats from their employees or when their capacity is severely limited (Krajewski, Ritzman, Malhotra: 2013).

To decrease the rate of demand, the primary lever would be to link the rate of demand with the rate of production. Other levers are the following:

1. Make use of promotional campaigns during not season time.

2. Provide new products that have a different demand cycle to that of the existing product so that the demand for one product with high demand during low season replaces the one with low demand during the same season.

3. Suggest your customer seasonal pricing plans (Krajewski, Ritzman, Malhotra: 2013).

Pipeline Inventory. Refers to an inventory that is generated when an order for a product is given out but still not yet collected. Pipeline inventory is used when the firms must show commitment that it has enough inventory as well as cover the order's lead time. More pipeline inventory is created by higher demands per week or lasting lead times. "*As such, between any two stocking points, the average pipeline inventory is considered as he average demand during the lead time,* $\overline{D}_L$ *, which is an indication of the average demand per period (*$\overline{d}$*)*

multiplied by the number of periods in the lead time of the items (L) to move between two points as follows:

$$\text{Pipeline inventory} = \overline{D}_L = \overline{d}L$$

In this equation, it is assumed that both $\overline{d}$ *and L are constants and that the order or the lot size Q does not affect L."* The average level of the pipeline inventory is not directly affected by changing the size of the lot. However, indirect changes in the size of the lot affects pipeline inventory in case if it is related to the lead time (Krajewski, Ritzman, Malhotra: 2013).

A manager of operations can control the lead time but not the rate of demand. The primary lever to reduce the pipeline goes through reduction of lead time as pipeline inventory is given as a function of demand during lead time. Additionally, there are two main secondary levers that can help in the reduction of lead time:

1. Choose suppliers who are more responsive or make better the material treatment function of the plant. Information detention between retailers and distributors have to be refine by improving the information system.

2. In cases where the lead time is dependent on the size of the lot, Q should be changed (Krajewski, Ritzman, Malhotra: 2013).

3.1.3 Inventory control systems

Inventory control systems are useful in the determination of when to order based on the market conditions. There are two types of inventory control system called the periodic review system (P system) and the continuous review system (Q system). Here, consideration is given to the Q system as it is the one which is used in the case company.

A continuous review (Q) system is also called a reorder point (ROP) system. It is a system that is developed for tracking of what is left in stock of inventory each time an item is taken from the inventory and therefore helps in determining whether it is time to reorder or not. In practice these checking is done on daily basis.

A reorder point (R) is established minimum level of stock. When the inventory position reaches point R, a fixed quantity Q of units for store keeping purposes is reordered. The time between orders can vary in a continuous review system even with a fixed order quantity. Hence, Q can be based on a container size, economic order quantity (ECQ) or the quantity which will provide some total discount (Krajewski, Ritzman, Malhotra: 2013).

A theory proposed by Krajewski, Ritzman, Malhotra (2013) indicated that in a continuous review system, reorder points are selected based on three cases. In the first case, lead time and case demand are held constant. In the second option, the lead time is held constant while the demand is changing. In the third case, the lead time and demand are both changing. The first case is impractical as it indicates that demand is always constant as in the formula:

$$R = \bar{d}L$$

Where R – reorder point

$\bar{d}$ - average demand

L=lead time

This equation is illustrated in Figure 7

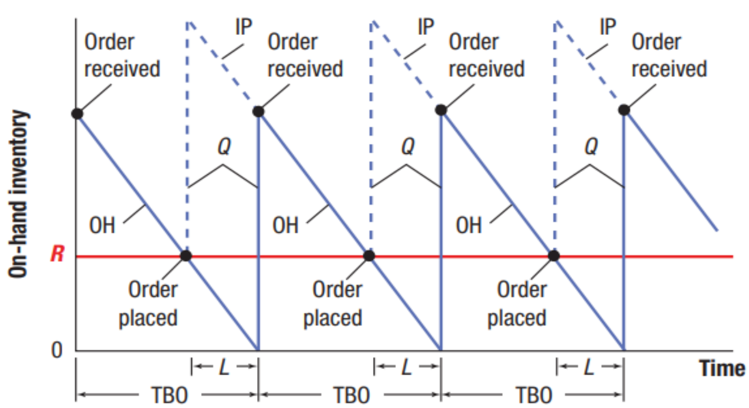

Figure 7: Q system for the first case in which the lead time and demand are constant (Krajewski, Ritzman, Malhotra: 2013).

In practice, however, demand greatly varies and for most part, uncertain. This calls for the need of safety stocks and therefore making the following formula acceptable for the second case and third case

$$R = \bar{d}L + \text{safety stock}$$

The second option and third option only have differences in the way safety stock is calculated. With the high precision, standard deviation as a result of the demand during lead time causes the only difference. Safety stock in the second case follows:

$\text{Safety stock} = z\sigma_{dLT}$, where

z = *"the number of standard deviations needed to achieve the cycle service level"*

σ_{dLT} = *"standard deviation of demand during the lead time"*, which is again calculated as

$\sigma_{dLT} = \sqrt{\sigma_d^2 L} = \sigma_d \sqrt{L}$, where

L=lead time

σ_d^2 = standard deviation of demand

On the other hand, safety stock for the third case is calculated using the following formula (Krajewski, Ritzman, Malhotra: 2013):

$\text{Safety stock} = z\sigma_{dLT}$, where

z = *"the number of standard deviations needed to achieve the cycle service level"*

σ_{dLT} ="*standard deviation of demand during the lead time*", which is again calculated as

$\sigma_{dLT} = \sqrt{\overline{L}\sigma_d^2 + \overline{d}^2\sigma_{LT}^2}$, where

$\overline{d}$ = Average weekly (or daily or monthly) demand

$\overline{L}$ = Average weekly (or daily or monthly) lead time

σ_d = Standard deviation of weekly (or daily or monthly) demand

σ_{LT} = Standard deviation of the lead time, and

In calculating safety stock, σ_d and z are attained as follows: to achieve z, a cycle-service level or the service level that starts when the order is placed and ends on arrival of the stock – representing probability of not being in situation where there is no stock and nothing to suggest to the customer. Normal Probability Distribution is used to establish this probability (Krajewski, Ritzman, Malhotra: 2013).

To find σ_d, daily/weekly/monthly standard deviation which is *"the measure of spread of data around the mean value of the data*", the following formula is used:

$$\mathrm{SD} = \sqrt{\frac{\sum |x-\mu|^2}{N}}$$

Where

∑=sum of

x= a value in the data set

μ= the mean of the data set

N= the number of data points in the population (The Organic Chemistry Tutor: 2017).

3.2 Forecasting

3.2.1 Importance of forecasting

In a supply chain, push processes are usually initiated in anticipation of demand from the customer side. On the other hand, pull processes are initiated in reply to demand of the customer. This means that for push processes, a high level of planning from the manager side has to be undertake in areas of production, transportation and any other associated action. In a pull situation, the manager, on the other hand has to plan on how much capacity is needed as well as the inventory but not the actual needed amount. The manager, in these cases, should first forecast customer demand (Chopra &Meindl: 2016).

Through forecasts, many benefits accrue to the company. A company can use sale forecasts to plan its production, marketing, finances, and can be used by employees for personal planning. Additionally, when done properly, sales forecasts can help a company set proper prices for its goods favorable to itself and the market. Forecasts also help in sales zones reallocation. It also assists in the mitigation of over-stocking and understocking, reduce the need for overtime work, and eliminates slack periods in which employees are idle (Gupta: 2013).

The features of forecasting include the following:

1. Forecasts are not perfect and therefore they should include both an expected value plus a margin of error
2. Short-term forecasts are more accurate than long term forecasts
3. Disaggregated forecasts have lower accuracy than aggregated forecast
4. Forecasts for companies up in the supply chain are more distorted compared to those lower in the supply chain (Chopra & Meindl: 2016).

3.2.2 Forecasting methods

Methods of forecasting come in four main classes (Chopra &Meindl 2016):

1. *Qualitative.* These methods rely on judgment provided by people and therefore considered as subjective. Qualitative forecasting is suitable when knowledge about the market is available through competence of experts or there is little historical data. New industries may also find qualitative forecasts to be helpful in forecasting demand.
2. *Time series.* This method of forecasting makes use of historical data available to forecast demand. Time series technique suspects that information on demand in the past provides good indication of the demand in the future. Time series forecasting is very suitable when there is no significant variation in the demand pattern from year to year. Therefore, this method is easy and may act as a good beginning for forecasting a demand.
3. *Causal.* In this method it is assumed that there is a close link between demand forecast and some surrounding factors such as for example interest rates, economy behaviour. Using this relationship, casual forecasting methods estimate how changes in environmental factors can affect future demand. For example, there is a strong correlation between the prices of product and demand. This relationship can be used by a firm to determine how demand is affected by price promotions.
4. *Simulation.* This method works by imitating the choices that customers make and thus affect the level of demand. Simulation allows the combination of casual and time-series forecasting method.

Any demand that is observed is splited into two components: random and systematic components.

Observed demand (O) is splited into two main components: the random component (R) and systematic component (S) as in the following equations:

O = S + R

"The systematic component measures the expected value of demand and consists of what we will call level, the current deseasonalized demand; trend, the rate of growth or decline in

demand for the next period; and seasonality, the predictable seasonal fluctuations in demand" (Chopra &Meindl: 2016).

Systematic component calculation can be done in different ways illustrated below:

1. *"Addition: S = trend + level +seasonal factor"*
2. *"Multiplication: S = level*trend*seasonal factor"*
3. *"Mixed: S = (level + trend) * seasonal factor"*

On the other hand, the component of the demand that is different to systematic part is known as the random component. Forecasting the path of the random component is not possible. However, the company can forecast the variability and the size of the random component through the forecast error (Chopra &Meindl: 2016).

3.2.2.1 Qualitative forecasting

3.2.2.1.1 Salesforce estimates

The compilation of period sales estimates made by members of a salesforce team of a company is referred to as salesforce estimates. Additionally, the term salesforce is used to describe a group of salespeople who would have the ability to know which products or services and in what amount that customers would be purchasing in the future. A combination of the predictions made by different members of a salesforce team can be done to yield national or regional sales estimates. However, different personality of people may affect the credibility of the forecast, making it to be either too optimistic or negative (Krajewski, Ritzman, Malhotra: 2013).

3.2.2.1.2 Executive Opinion

This refers to a type of qualitative forecasting in which managers have a meeting to combine their individual forecasts to yield a single forecast. Executive forecasting is normally used in predicting the achievement of a new product in the market or for strategic forecasting. In unusual scenarios, executive opinion forecasts are used to modify the existing forecasts so that the unusual scenarios (such as unexpected competition) can be considered. Though executive opinion forecasting can provide good insights for the sales of a company, this method comes with several disadvantages. For example, the opinion of a powerful member can have a lot of influence on the opinion of the others (Reid&Sanders: 2010).

3.2.2.1.3 Market Research

Market research is a forecasting method that makes use of conventional methods such as interviews and surveys to predict the wish, needs, likes and dislikes of the customers with the goals of determining new ideas for developing products. This method provides good information; however, the development of good enough questionnaire is not easy (Reid&Sanders: 2010).

3.2.2.1.4 Delphi Method

The Delphi method of predicting market demand uses a group of experts who provide their prediction anonymously. The Delphi method is suitable when no historical data for the development of statistical models for prediction exist. Additionally, this method is also suitable when the basis for making decisions is lacking among the managers due to inexperience.

Through the use of coordination, an organization develops and sends questions to each expert in the group (experts have no idea about the participation of other experts). The collected responses are then summarized by the coordinator as well as the summary of the arguments that support particular points of view. Once report compilation is done, the coordinator then sends it to the experts for their opinion with the option of modifying their earlier responses. Another round of report is then combined and sent to experts until a consensus is reached (Krajewski, Ritzman, Malhotra: 2013). The rationale behind the use of the Delphi method is that experts drawn from a certain field may not agree on several issues, but when they do agree, that situation is likely to happen. Therefore, the work of coordinator is the identification of the points of agreement by the experts and making use of those points in his/her creation of forecast. Delphi method is good as it ensures that all members' opinion is respected without one dominating the forecast. As such, this method has been shown to work well especially in predicting the demand of products in the long range and in situations where there may be significant technological change and development in medicine (Reid&Sanders: 2010). However, it consumes a lot of time.

3.2.2.2 Quantitative forecasting: Time series methods

3.2.2.2.1 Naïve method

The naïve method is easy forecasting method, which does not suggest any change for the next period. The forecast of the next period is equal to actual value of current period (Reid&Sanders:2010):

$$F_{t+1} = A_t$$

F_{t+1} = forecast for next period, $t + 1$
A_t = actual value for current period, t
t = current time period

3.2.2.2.2 Average

Average forecast also called simple mean forecast as it is calculated by summing up actual values of past periods divided by number of periods (Reid&Sanders:2010):

$$F_{t+1} = \frac{\Sigma A_t}{n} = \frac{A_t + A_{t-1} + \cdots + A_{t-n}}{n}$$

F_{t+1} = forecast of demand for next period, $t + 1$
A_t = actual value for current period, t
n = number of periods or data points to be averaged

3.2.2.2.3 Moving Average

The Moving Average is forecasting method which works when there is no visible trend or seasonality in demand. Consequently, systematic component of demand is equal to level.

The level in period t in this method is calculated as the average divided by number of N periods. This is represented as:

$$L_t = (D_t + D_{t-1} + \ldots + D_{t-N+1}) / \mathrm{N}$$

The future forecast is equal to level and is stated as:

$$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$

Level in period t+1 is calculated as follow:

$$L_{t+1} = (D_{t+1} + D_t + \ldots + D_{t-N+2}) / N, \quad F_{t+2} = L_{t+1}$$

New moving average is calculated by adding the newest value and dropping the oldest value (Chopra &Meindl: 2016).

3.2.2.2.4 Simple Exponential Smoothing

The first step to implement Simple Exponential Smoothing is to calculate average, what is demonstrated in formula below. Simple Exponential Smoothing method reminds moving average method in a way that both are used when there is no visible trend or seasonality. Thus, systematic component of demand is equal to level.

$$L_0 = \frac{1}{n}\sum_{i=1}^{n} D_i$$

The forecast is equal to level:

$$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$

After demand calculation, D_{t+1} for period t+1, level estimate is changed in following way:

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha)L_t$$

"Where α is a smoothing constant for the level, 0 < α < 1, which can be any number between 0 and 1. The revised value of the level is a weighted average of the observed value of the level (D_{t+1}) in period t +1 and the old estimate of the level (L_t) in Period t (Chopra &Meindl: 2016)." Thus, final formula is:

$$L_{t+1} = \sum_{n=0}^{t-1} \alpha(1-\alpha)^n D_{t+1-n} + (1-\alpha)^t D_1$$

Weighted average of all previous demand values with the newest values weighting more than the oldest one, serves as the current estimate of the level (Chopra &Meindl: 2016).

3.2.2.2.5 Double Exponential Smoothing (Holt's model)

Double Exponential Smoothing method, also named as Holt's model is suitable when demand is expected to have trend and level in the systematic component but without seasonality features. Thus, systematic component of demand is equal to sum of trend and level.

Initial estimates of level and trend are calculated by implementing a linear regression between demand D_t and time Period t of the form D_t = at + b. Here, implementation of linear regression between time periods and demand is good because of expectation that demand has a trend but no seasonality. *"The constant b measures the estimate of demand at Period t = 0 and is estimate of the initial level L_0. The slope measures the rate of change in demand per period* *and is initial estimate of the trend T_0 (Chopra &Meindl: 2016).”* Thus, future periods are forecasted as:

$$F_{t+1} = L_t + T_t \quad \text{and} \quad F_{t+n} = L_t + nT_t$$

After observing demand for Period t, the estimates for level and trend are:

$$L_{t+1} = \alpha D_{t+1} + (1 - \alpha)(L_t + T_t)$$
$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$

“Where α is a smoothing constant for the level, 0 < α < 1, and β is a smoothing constant for the trend, 0 < β < 1 (Chopra &Meindl: 2016).”

3.2.2.2.6 Triple Exponential Smoothing (Holt-Winters model)

Triple Exponential Smoothing is forecasting method which is also called Holt-Winters model. It goes further than Double Exponential Smoothing in a way that it considers seasonality in demand forecasting. Systematic component of demand is calculated as a sum of level and trend multiplied by seasonal factor (Chopra &Meindl: 2016).

Assume periodicity of demand to be p. Initial estimates of level (L_0), trend (T_0) and seasonal factors (S_1, ... , S_p) can be obtained using two procedures which are described below. The difference in procedures appears, because in first procedure initial estimates come through linear regression which are not used in second procedure. Overall, idea is the same, however first procedure demonstrates formulas when Period = 4(quarterly) while in second procedure Period = 12 (monthly).

First procedure

1. Estimation of level and trend: Firstly, the aim is to determine the level and trend at period 0. It is done by deseasonalizing demand. Deseasonalized demand means demand which exists when seasonal fluctuations are not present. Number of periods p, means periodicity after which seasonal cycle repeats again. In order to guarantee that each season is equally important during performance of deseasonalizing, the

average of periods is used. *"The average of demand from Period l + 1 to Period l + p provides deseasonalized demand for Period l + (p + 1)/2. If P is odd, this method provides deseasonalized demand for an existing period. If p is even, this method provides deseasonalized demand at a point between Period l + (p/2) and l + 1 + (p/2). By taking the average of deaseasonalized demand provided by Periods l+ 1 to l+ p and l + 2 to l + p + 1, the deseasonalized demand for Period l + 1 + (p/2) is obtained. This procedure for obtaining the deseasonalized demand,* $\overline{D}_t$*,for Period t, is formulated as follows:*

$$\overline{D}_t = \begin{cases} \left[D_{t-(p/2)} + D_{t+(p/2)} + \sum_{i=t+1-(p/2)}^{t-1+(p/2)} 2D_i \right] \Big/ 2p \text{ for } p \text{ even} \\ \sum_{i=t-(p/2)}^{t+(p/2)} D_i/p \text{ for } p \text{ odd} \end{cases}$$

Linear relationship exists between the deseasonalized demand, $\overline{D}_t$*, and time t, based on the change in demand over time:*

$\overline{D}_t = L + Tt$ *, where*

The initial level, L, is obtained as the intercept coefficient and the initial trend, T, is obtained as the X variable coefficient (or the slope) from linear regression with deseasonalized demand (Chopra &Meindl: 2016)."

2. Estimation of seasonal factor: After observing level and trend by performing demand deseasonalizing, seasonal factor can be found. *"The seasonal factor* $\overline{S}_t$ *for Period t is the ratio of actual demand D to deseasonalized demand* $\overline{D}_t$ *and is given as:*

$$\overline{S}_t = \frac{D_i}{\overline{D}_t}$$

Given the periodicity, p, the seasonal factor is obtained for a given period by averaging seasonal factors that correspond to similar periods. For example, if a periodicity of p= 4, Periods 1,5,9 have similar seasonal factors. The seasonal factor for these periods is obtained as the average of the three seasonal factors. Given r *seasonal cycles in the data, for all periods of the form pt + i,* $1 \leq i \leq p$ *the seasonal factor is":*

$$S_i = \frac{\sum_{j=0}^{r-1} \bar{S}_{jp+i}}{r}$$ (Chopra &Meindl 2016).

Second procedure

1. Estimation of seasonal factor: Take each of actual sales values (Y_1) in starting year and compare it to average of sales monthly (Y_1:Y_{12}) (Major: 2018).

2. Estimation of level: Take level$_{13}$ (L_{13}) as initial level dividing actual sales$_{13}$ (Y_{13}) by season$_1$ (S_1) (Major: 2018).

   Estimation of trend: Take trend as difference between level$_{13}$ (L_{13}) and division of previous year's actual sales of last month (Y_{12}) by seasonal factor of last month of previous year (S_{12}) (Major: 2018).

Thus the formulas are:

$S_1 = \frac{Y_1}{average(Y_1;Y_{12})}$; $S_2 = \frac{Y_2}{average(Y_1;Y_{12})}$,…, $S_{12} = \frac{Y_{12}}{average(Y_1;Y_{12})}$

$L_{13} = \frac{Y_{13}}{S_1}$

$T_{13} = \frac{Y_{13}}{S_1} - \frac{Y_{12}}{S_{12}}$ (Major: 2018).

After initial estimates are obtained, next formulas are the same for both procedures described above.

Triple Exponential Smoothing Method can be performed using multiplicative or additive method. If in original data seasonal fluctuations are stable – additive model should be used. If in original data seasonal fluctuations are with variations – multiplicative model should be used (Setiawan, Juniati, Farida: 2016).

*"If the seasonality is **multiplicative** then the three smoothing equations pertaining to level, trend and seasonality of p-period cycles are given by*:

$L_t= \alpha(Y_t/S_{t-p}) + (1 - \alpha)*(L_{t-1}+ T_{t-1})$

$T_t = \beta (L_t- L_{t-1}) + (1 - \beta)*T_{t-1}$

$S_t = \gamma (Y_t/L_t) + (1 - \gamma)*S_{t-p}$

where S_t is seasonality adjusting equation, p is the number of period in seasonal cycle, α is a smoothing constant for the level, $0 < \alpha < 1$, and β is a smoothing constant for the trend, $0 < \beta < 1$, γ is seasonal smoothing parameter such that $0 < \gamma < 1$.

The forecast equation h-steps ahead at time t with multiplicative seasonality is given by

$F_{t+h} = (L_t + hT_t)*S_{t-p+h}$, h = 1, 2, 3, . . (Marera: 2016)."

*"If the seasonality is **additive**, the smoothing equations are given by*

$L_t = \alpha(Y_t - S_{t-p}) + (1 - \alpha)*(L_{t-1} + T_{t-1})$

$T_t= \beta (L_t - L_{t-1}) + (1 - \beta)*T_{t-1}$

$S_t = \gamma(Y_t - L_t) + (1 - \gamma)*S_{t-p}$

where S_t is seasonality adjusting equation, p is the number of period in seasonal cycle, α is a smoothing constant for the level, $0 < \alpha < 1$, and β is a smoothing constant for the trend, $0 < \beta < 1$, γ is seasonal smoothing parameter such that $0 < \gamma < 1$. The forecast equation at time t with additive seasonality is given by

$F_{t+h} = L_t + hT_t + S_{t-p+h}$, h = 1, 2, 3, . .(Marera: 2016)."

Use of Holt-Winters model is problematic, because it is difficult to estimate optimized values of α, β and γ so that error can be minimized. First method to determine the values is done with errors calculations (Chusyairi, Ramadar, Bagio: 2017). There is also another method - Excel solver (excel based non-linear optimization tool), which helps to determine the values. "*Under trial and error method, for different values of exponential smoothing constant, MAD and MSE are calculated and optimized by minimization. In Excel Solver, the first step is to* *prepare the spreadsheet for representing the model. Once the model is implemented, next step is to call the Solver to find the optimum solution. At third step, the locations (position of cells) of objective function, decision variables, nature of the objective function (maximize/minimize) and constraints are determined"* (Karmaker: 2017). Both methods will deliver approximately the same results, however Excel Solver is simpler and requires smaller amount of time for provision of optimum solution.

3.2.3 Forecast error

There are multiple methods used to indicate the size of error after performing chosen forecast method (Klimberg, Sillup, Boyle, Tavva: 2010).

Mean absolute deviation (MAD) is the famous method to show forecast error. *"The MAD is calculated as the average of the absolute errors:*

$$\mathrm{MAD} = \frac{\sum |Y_t - F_t|}{n}$$

where t = time period; n = number of periods forecasted; Y_t *= actual value in time period t;* F_t *= forecast value in time period t. (Klimberg, Sillup, Boyle, Tavva: 2010)."* MAD value is better when it is smaller.

Another primary forecasting performance measure of the size of the error is the mean square error (MSE). *"The MSE is calculated as the average of the sum of the squares of forecast the errors:"*

$$\mathrm{MSE} = \frac{\sum (Y_t - F_t)^2}{n}$$

Dispersion of errors is measured by MSE value, and the smaller value is – better it is as in the case with MAD. *"The square root of the MSE results in the standard deviation of the errors or standard error* (s_e) *and is sometimes called the root mean square error (RMSE)":*

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$ (Chai, Draxler:2014).

Significant negative side of the MAD and MSE forecasting evaluations is that they do not consider the magnitude of actual values. That is why mean absolute percentage error (MAPE) was developed. This method eliminates shortcomings of MAD and MSE. *"The MAPE is calculated as: the average of the absolute values of percentage errors"* (Klimberg, Sillup, Boyle, Tavva: 2010):

$$\text{MAPE} = \frac{\sum \frac{|Y_t - F_t|}{Y_t}}{n}$$

Forecast model is more accurate when MAPE is low, the same as with MAD and MSE. Lewis's scale presented in Table 5 provides framework for judgment of the model (Klimberg, Sillup, Boyle, Tavva: 2010).

Table 5. A scale of judgment of forecast accuracy developed by Lewis (1982).

MAPE	**Forecast Accuracy Evaluation**
Less than 10%	Forecast accuracy is very high
11% to 20%	Forecast is good
21% to 50%	Forecast is acceptable
51% or more	Forecast is not accurate

4 RESULTS ON PERFORMANCE OF VSM AND ANALYSIS OF IDENTIFIED WASTE

4.1 Implementation of VSM in case company

4.1.1 Selection of product family

VILPE Oy has high mix of products, however only few of them pass through all production processes. Product category consisted of P-series roof fans (P-sarjan huippuimurit) was selected for investigation in order to include the longest route of production. Roof fans differ in sizes and type of motors, giving in total 8 versions of the product. In addition, each version can be produced in 7 colours. Sales from years 2016 – 2017 reflected that 2 versions of the product are the most demanded as within the product category as among all other products produced by the company.

Table 6. Selected products for VSM based on the highest sales figures.

Name of the product; Product number	**Color**
VILPE®E120P/125/700 Roof fan; 73482	Black
VILPE®E190P/125/700 Roof fan; 73532	Black

4.1.2 Construction of current state map

4.1.2.1 Cycle time, setup time and changeover time

For product 73482 – 5 components are produced in injection molding process. Each component is produced with different cycle time; however, the longest time is selected to represent cycle time of this process. The same is true for compression process, where 2 components are produced with different cycle times and the longest time is selected to represent the process. For the product 73532 the longest cycle times are also chosen to represent these processes.

For product 73482 – 5 machines are producing the components in injection molding process, where 4 out of 5 machines have the same setup time equal to 60 minutes. However, the longest time, which is equal to 90 minutes is selected to represent setup time of the process. The same is true for compression process, where 2 machines have different setup time equal to 10 minutes and 20 minutes and the longest time will represent the process. Machines for product 73532 have longer setup time in comparison with machines producing product 73482. Most of machines in injection molding process have setup time equal to 90 minutes, however the longest setup time is equal to 120 minutes. Instead of compression process, product 73532 has sealing process with one setup time equal to 15 minutes.

For product 73482 – 5 machines in injection molding have different changeover time and the longest time is selected to represent the process. Injection process is the only process where changeover time occurs. The situation is the same also for product 73532. In this case change of colour in the machine is meant by changeover time.

Average cycle time, set up time and changeover time of two products for each process are calculated and shown in VSM in Table 7.

Table 7. Cycle time, setup time and changeover time of products 73482 and 73532.

	Cycle time (minutes)			Set up time (minutes)			Changeover time (minutes)		
	73482	73532	**Average**	73482	73532	**Average**	73482	73532	**Average**
Injection molding	1,49	1,44	**1,5**	90	120	**105**	2,25	2,25	**2,25**
Compression/Sealing	4,22	0,66	**2,4**	20	15	**18**			
Top assembly	8,46	6,94	**7,7**	5	5	**5**			
Bottom assembly	2,32	6,90	**4,6**	1	1	**1**			
Final assembly/testing/packaging	4,6	4,6	**4,6**	5	5	**5**			

4.1.2.2 Takt time

Takt time shows how frequently a sold unit must be produced to satisfy customer’s need. The formula used to calculate takt time is

$$\textbf{Takt time} = \frac{Net\ available\ working\ time\ per\ day}{Customer\ demand\ \ per\ day}$$

First net available working time per day and customer demand per day were observed.

1. Net available working time is 7 hours 35 minutes or 27300 seconds:

1 shift	8 hours 30 minutes
Lunch time	30 minutes
Coffee breaks	2×12,5 minutes = 25 minutes

2. Customer demand is 18 pieces/day

	73482 E120P/Ø125/700 Roof fan Black	73532 E190P/Ø125/700 Roof fan Black
2016	2419	2129
2017	3014	1913
Average demand of years 2017-2016	2717	2021
Montly demand of years 2017-2016	226	168
Daily demand (22 working days in month)	10	8
	Sum of daily demand of both products	18

Thus,

$$\textbf{takt time} = \frac{27300\ seconds}{18\ pieces} = 1517\ seconds = 25\ minutes$$

4.1.2.3 Takt time and cycle time comparison

Cycle time of each process is compared to takt time. Cycle times are less than takt time, meaning that process is capable of meeting demand of customers. However, it is recommendable to keep cycle time at level of 80% - 90% of takt time, meaning that in ideal situation times need to be close (Lee&Snyder 2006: 68). In the company, cycle time is much lower than takt time, what can be the reason of waste formation in form of overproduction, excessive inventory and idle time of operators.

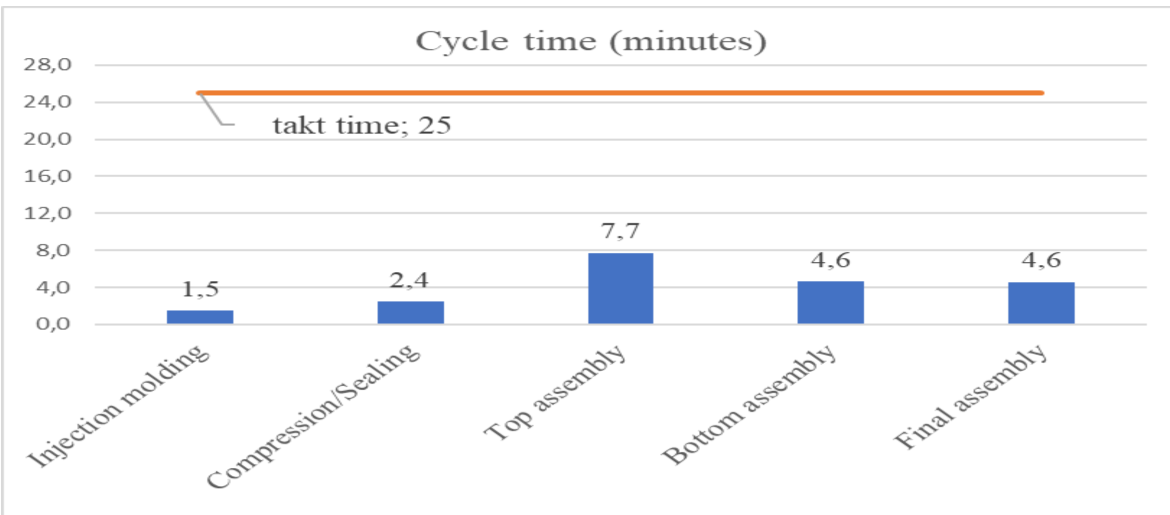

Figure 8. Takt time and average cycle time for each process for products 73482 and 73532.

4.1.2.4 Setup time and lot size

Setup time for each process is plotted and shown in Figure 9. Setup time in injection molding is the highest and lot size of this process is the largest among other processes, what is shown on Figure 10. Consequently, there is a need to reduce setup time of injection molding so that it is more in line with times for other processes. Reduction in setup time in injection molding would allow to reduce lot size of the process, what can lead to minimization of WIP inventory.

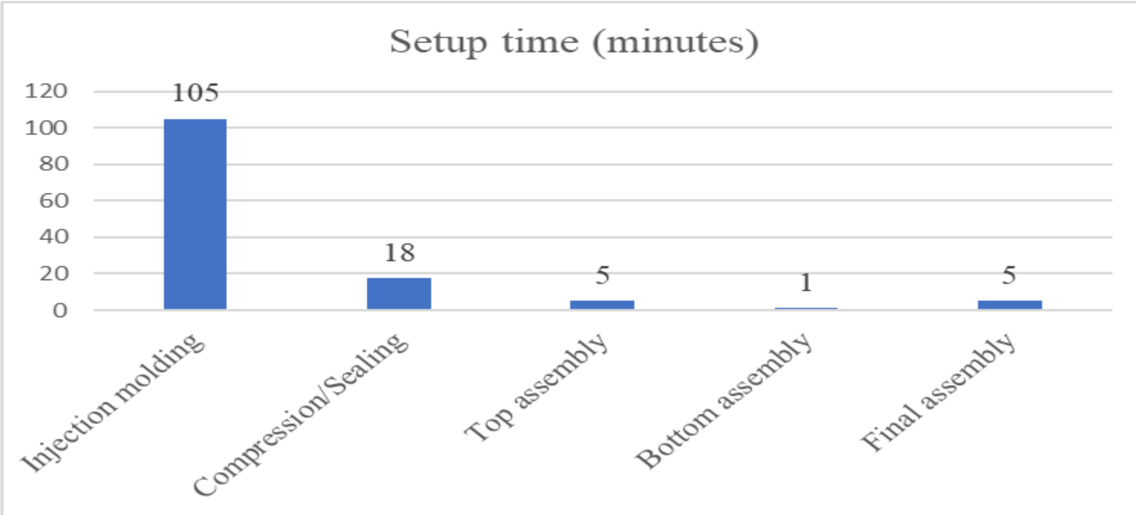

Figure 9. Average set up time for each process for products 73482 and 73532.

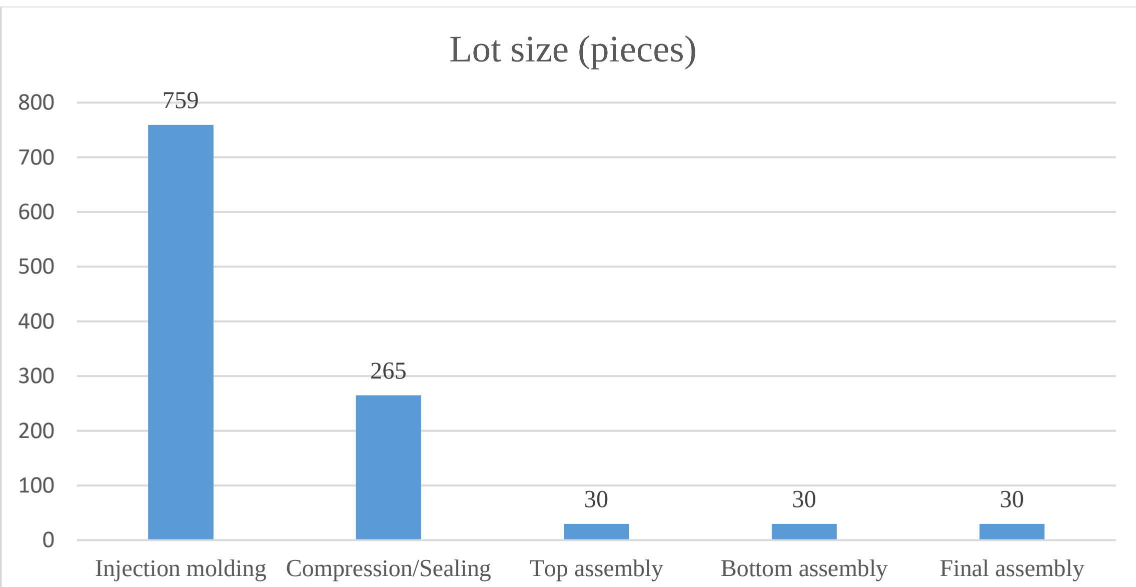

Figure 10. Average lot sizes in the processes of products 73482 and 73532.

4.1.2.5 Inventory

"Lead time (in days/months) for each inventory triangle is calculated as follow: inventory quantity divided by the daily customer requirement"(Rother&Shook 2003b: 30). Thus, the formula used is

$$\textbf{Inventory lead time} = \frac{Inventory\ quantity}{Customer\ daily\ demand}$$

There are 4 locations of inventory in the company. Inventory 1 consists of raw materials; Inventories 2 and 3 are WIP inventories which consist from produced components and purchased components; Inventory 4 is for finished goods. Inventory quantity is calculated based on re-order point at particular time, which is basically moving average being slightly higher or lower depending on time. All raw-materials and components found in the inventories are converted into the equivalent quantity of finished goods. In most cases 1 piece of component is equal to 1 piece of unit. However, only significant materials and components are considered in calculations of inventories, thus for example reserves of screws and stickers were disregarded. When there is more than one representative material/component in the inventory, the average of their re-order points is calculated. Raw materials for products 73482 and 73532 are the same, consequently Inventory 1 is common for both products, so its value is the same. Raw materials are also the same for other products as within product family as in another product families. Overall one raw material is used for production of 1157 products and another raw material is used in production of 259 products, including analysed products. Therefore, only 0,17% and 0,77% of given raw materials are applied in products 73482 and 73532, thus 0,17% and 0,77% of re-order points are calculated. Inventory 2 and Inventory 3 are also considered to be common for both products. Components are also the same for other products as within product family as in another product families. Inventory 2 is calculated based on re-order points of motor (purchased component) and top part (produced component). Motor is used overall in 80 products, including products 73482 and 73532, consequently only 3% of motors is used in investigated products, thus 3% of re-order point has to be calculated. The same is true for top part, which is used in 34 products, consequently only 6% of top parts are applied in investigated products and 6% of re-order point is calculated. Level of Inventory 3 is equal to zero. It is explained by the fact that roof fans are not accumulated while waiting for final assembly, testing and packaging. Even if elements of roof fans do not undergo final assembly at the same day, it will happen on next day, meaning that record of Inventory 3 is irrelevant.

Table 8. Number of units in inventories for product 73482.

Inventory 1	Inventory 2	Inventory 3	Inventory 4
37	20	0	202

Table 9. Number of units in inventories for product 73532.

Inventory 1	Inventory 2	Inventory 3	Inventory 4
37	20	0	165

To calculate inventory lead time, Inventory 4 for both products are combined, but Inventories 1, 2, 3 are not combined as they are already common for both products. Inventory quantities are divided by daily demand of both products, which is equal to 18 pieces/day.

Table 10. Inventory lead time for products 73482 and 73532.

	Inventory 1	Inventory 2	Inventory 3	Inventory 4
Quantity in units	37	20	0	367
Inventory lead time in days	2	1	0	20

4.1.2.6 Machine uptime and First Pass Yield (FPY)

Uptime and FPY will not be demonstrated in VSM as data was not recorded before and process on data collection is just initiated in the company.

Figure 11 demonstrated below represents current state map of the company. According to VSM - value adding time is equal to 15 seconds, while lead time is 24 days. Lead time is long because of the waste caused mostly by end – product inventory.

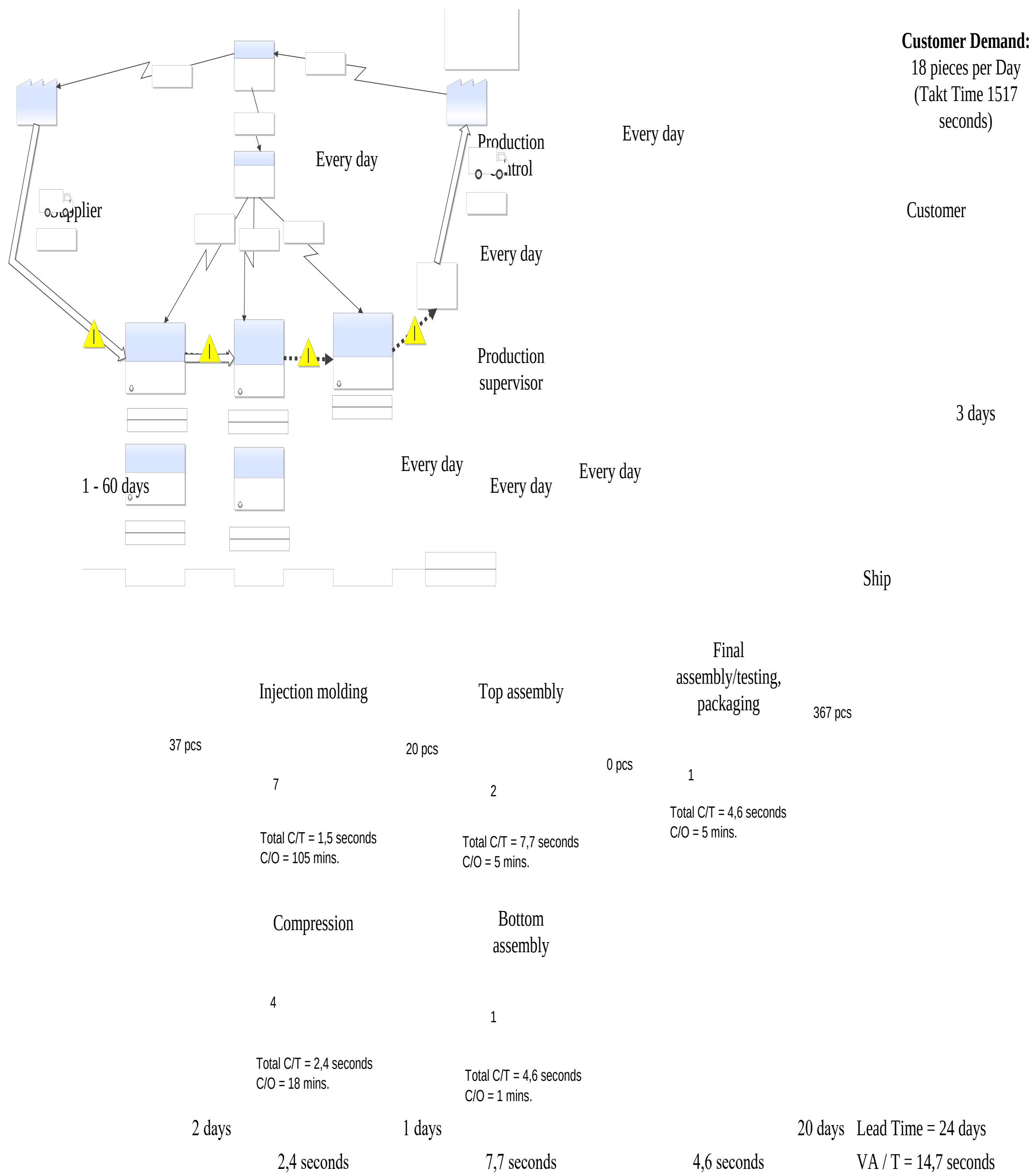

Figure 11. VSM of the company. Created in iGrafx Origins Release (2018).

4.2 Discussion with case company on results of VSM

Utilization of VSM tool helped to identify the following problems in the company:

1. Takt time is too high in comparison with cycle time
2. High set up time in injection moulding process resulting in big lot size
3. High level of end-product inventory
4. Gap in information flow in form of absent customer´s forecast

VSM helped to identify wastes in form of overproduction (takt time and cycle time mismatch – producing faster than needed; big lot size – producing more than needed) and inventory. In addition, wastes in form of defects, motion and transportation could be identified, however it was not done in this study. Defects were not identified in VSM because the company is just initiating the practices of recording information related to measurement of defects. Motion and transportation wastes were not observed, because these wastes were explored in VILPE Oy before, that is why traditional VSM model was applied without being supported by Process Activity Mapping tool.

Overproduction in form of takt time and cycle time mismatch seems to be a problem faced only by production of two studied products (73482 and 73532), because if the whole product family is considered the problem is less relevant. Figure 12, supports this suggestion.

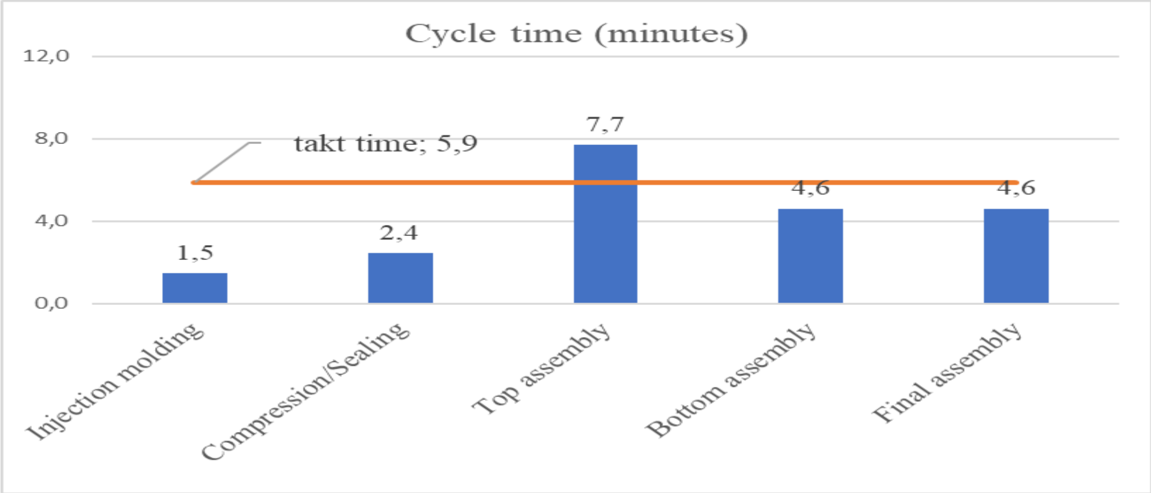

Figure 12. Takt time and average cycle time for each process for product family.

Figure 12 shows that if the whole product family is considered – overproduction exists mostly in injection molding process. However, cycle times of other processes are close to takt time. In case of top assembly cycle time is higher than takt time, meaning that process is not capable of meeting demand of customers and can be detected as bottleneck process.

The level of inventories is high, especially the level of end-product inventory. Consequently, the next steps are to view levels of physical inventories related to products 73532 and 73482 and how they are created suggested by Krajewski, Ritzman, Malhotra (2013) together with sales and production behaviour, as well as to invent methods to improve situation in inventory.

4.3 Analysis of identified waste

4.3.1 Analysis of inventory levels supplemented by levels of sales and production from 2012 to 2017

Inventory, production and sales are hand in hand aspects, therefore before performing analysis on inventory levels, behaviour of sales of products 73532 and 73482 from years 2012 – 2017 is considered.

Behavior of sales for products 73482 and 73532 from 2012 to 2017

Annual sales figures of products 73532 and 73482 as well as of entire product family from 2012 to 2017 were converted in form of percent change of sold units between years and achieved values were compared in Figure 13.

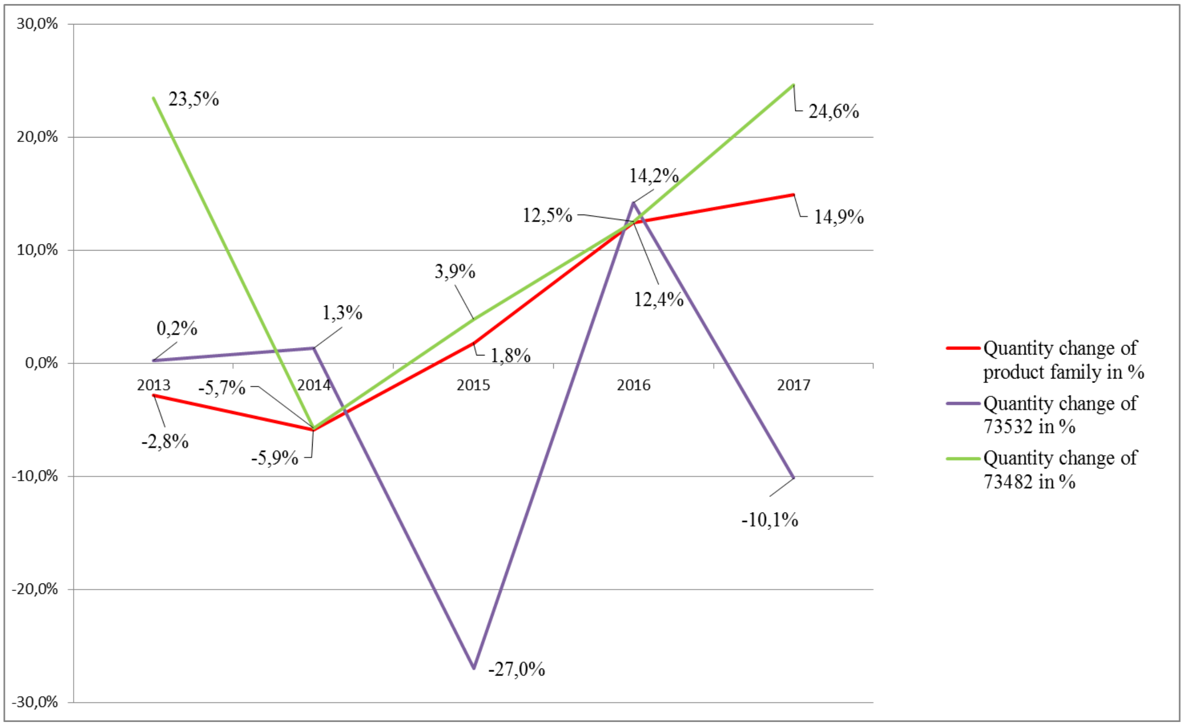

Figure 13. Comparison of change in sold units of product family and change in sold units of products 73482 and 73532 in percent (%) from years 2012 - 2017.

Figure 13 demonstrates significant difference between sold units of the product family and sold units of single products within the family from years 2012 – 2017. It can be seen that amount of sold units of the product family is decreasing from 2012 to 2014 and rising again from 2015 to 2017. Sold units of product 73482 mostly match behavior of all product family. However, sales of product 73532 do not match sales of the product family. Amount of sold units of 73532 from year 2012 to 2014 is increasing, while overall decrease in product family takes place. In 2015 amount of sold units of the product 73532 significantly decreases, while overall increase in product family is observed. In 2016, the amount of sold units is rising again as well as the level of sold units of product family. Finally, essential mismatch happens in 2017 when amount of sold units of product family continue to grow while amount of sold units of product 73532 decreases. Consequently, behavior of each product is unique and has to be considered individually.

End-product inventory together with sales and production monthly

End -product 73532

Changes in inventory together with ability of inventory and production to match sales monthly are demonstrated in Figure 14.

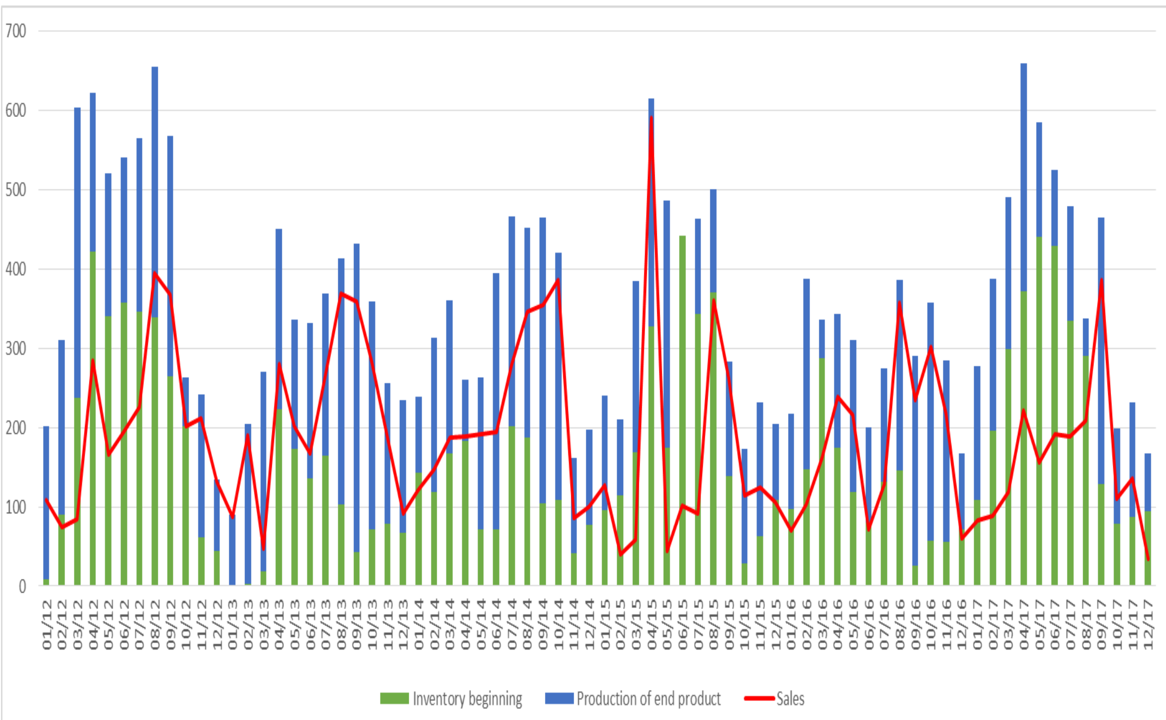

Figure 14. Comparison between levels of inventory and production of the end product with sales of the product 73532 monthly from years 2012 – 2017.

Figure 14 can be interpreted in the following way. High level of inventory outlined by utilization of Value Stream Mapping tool is based on year 2017. The level of inventory in years 2012 and 2017 is much higher than in 2013-2016. As was explained by factory supervisor, in 2012, the reason of high inventory was confusion in names of products in the system which led to lack of their availability, consequently more products were produced just in case to ensure security of supply. In 2017, the reason of high inventory level, especially in winter season, was aspiration to use available workforce, producing product in advance in order to prepare for summer season when demand starts significantly to grow while permanent workers go to vacations. Consequently, formed inventory is anticipation inventory. In years 2013 - 2016, inventory and production match the sales well in particular months of the years, when achievement of peak in sales is expected (August-September). In peak periods inventory mostly stays low and production is intensive aiming to satisfy sales orders. However, when minimum in sales takes place or period of growth in sales starts, level of inventory is still high while more units are continued to be produced. Situation is the same basically for all months besides 01/13 and 02/13 where level of stock dropped almost to zero so production needed to be fast in order to satisfy demand. Excessively high inventory levels in particular months in years 2015 can be explained by unexpectedly high order in 04/15 followed by assumption in production that situation can be repeated in next months, resulting in units being produced more than sales were able to sell.

End product 73482

Changes in inventory together with ability of inventory and production to match sales monthly are demonstrated in Figure 15.

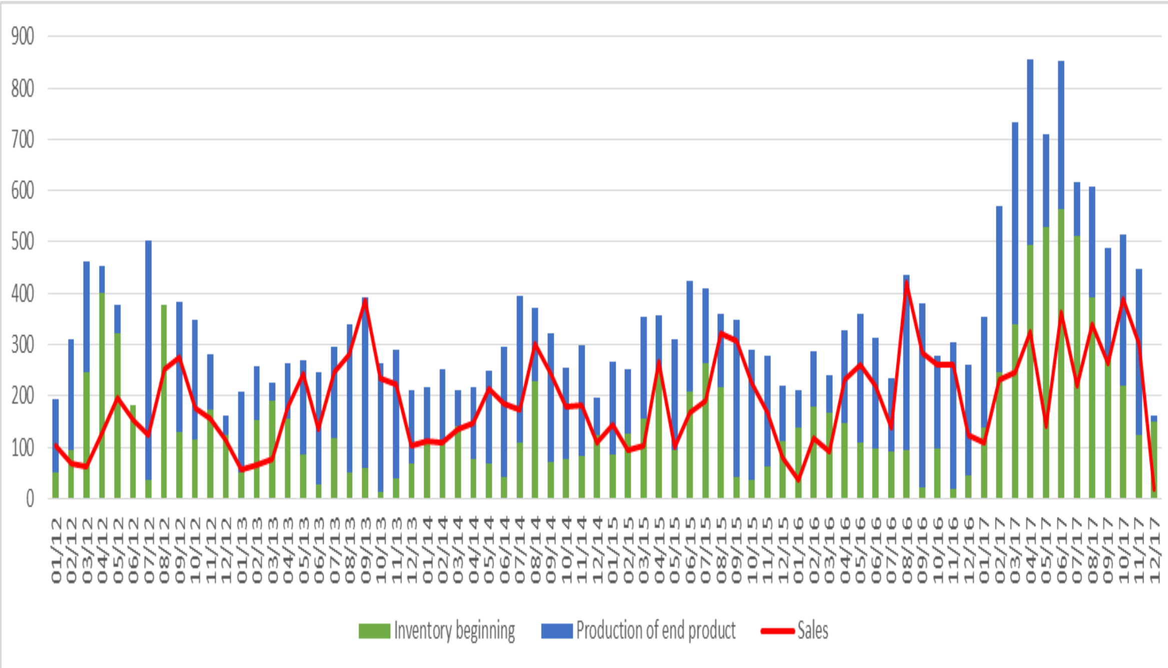

Figure 15. Comparison between levels of inventory and production of the end product with sales of the product 73482 monthly from years 2012 – 2017.

According to Figure 13, sales of product 73482 were increasing from year 2014. It explains why levels of inventory and production seem to be more synchronized with sales without that strong fluctuation as in product 73532. However, as with product 73532 in years 2013 – 2016, inventory and production of the product 73482 match the sales well in peak periods, while in periods of minimum and growth in sales, the level of inventory is still high, and more products are continued to be produced. In 2012 and 2017 inventory is higher than in previous years due to the same reasons as with product 73532 – confusion in names of products in the system and aim to use available workforce during low-demand season. In 2017, anticipation inventory is formed.

Inventory of component (WIP) together with its production and production of end products monthly

One of the components of roof fans is top part. Top part (H808702) is produced in the company, in injection molding process. This part can be used in many products; therefore, existing inventory and production of the top part are compared to production of end products where the part is used. There are 63 products, including product 73532, where the same top part is used. However, some of the products are not produced anymore, that is why inventory and production of the part will be compared to existing end products, which are in total 34. Inventory of component and its production are compared with production of end products instead of sales, because production of components is considered partly as pull process. As the top part is one of the most essential components of the products, its inventory and production are chosen to represent WIP inventory from production side as well as how well the whole production of components adapts to changes in production of end products.

Changes in inventory together with ability of inventory and production of top part to match production of end product monthly are shown in Figure 16.

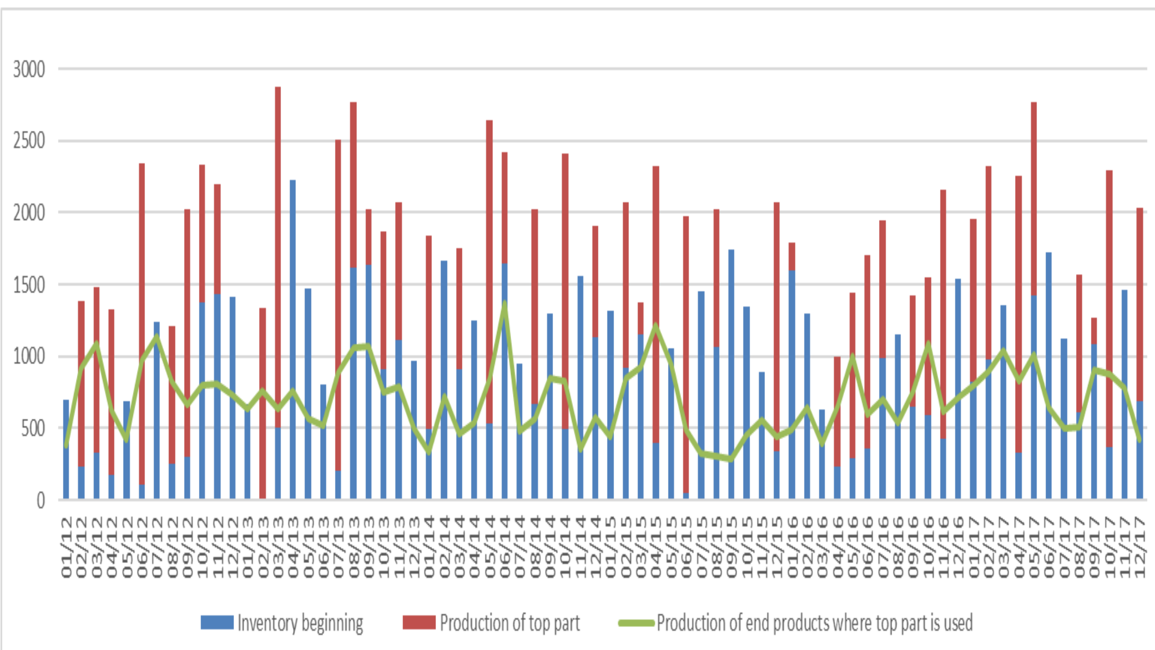

Figure 16. Comparison between levels of inventory and production of top part with production of the end products where top part (808702) is used monthly from years 2012-2017.

Based on Figure 16, there is a significant mismatch between production of end products and production of the top part. Mismatch is characterized by excessive inventory in several months of each year. From Figure 16, it can be noticed that production of component relies on inventory a lot. There are months when production of top part does not happen, but once top part is produced, usually it is done in huge lot size, resulting in several months inventories.

Inventory of motor (WIP) together with sales and procured amount monthly

Motor, which comes from supplier, is a significant element of the products. If not enough of motors are ordered, delays in production will take place, but big order size is the reason of formed inventory. One motor can be used in many products; therefore, procured amount and existing inventory of the motor will be compared to sales of all products where particular motor is used. There are 128 products, including products 73482 and 73532, where the same motor is used. However, some of the products are not produced anymore, that is why procurement and inventory of motors will be compared to sales of existing products, which are in total 80. As the motor is the most significant procured part, its inventory and procured quantity are chosen to represent WIP inventory from procurement side as well as how well the whole procurement department adapts to changes in sales.

Changes in inventory together with ability of inventory and procured amount to match sales monthly are shown in Figure 17.

Figure 17. Comparison between procured amount of motor and its inventory with sales of the products where particular motor is used monthly from years 2012 – 2017.

Figure 17 can be interpreted in following way. In periods of minimum and growth in sales, level of inventory is still high, and more products are continued to be procured in years 2012, 2014-2016 – partly repeating the situation of end products 73482 and 73532. Inventory and procured amount match sales well in peak time in all years beside year 2016. Extraordinary situation in year 2016 can be explained by the fact that in peak month of this year, procurement department negotiated its usual order size what has always been equal to 1152 to new order sizes 1526 and 768 units. In the end of 2016 procured order size changed, what helped to improve inventory behavior in year 2017. In 2017 inventory levels have started to follow behavior of sales, decreasing and increasing with drop and growth in sales.

Inventory of raw material together with procured amount and production of products monthly

Polypropylene, which comes from supplier, is basic raw material of produced products. If not enough of raw material is ordered, delays in production will take place, but big order size is the reason of formed inventory. One raw material is used in many products; therefore, procured amount and existing inventory of raw material will be compared to amount used for production of all products. There are 1157 products, including products 73482 and 73532, where the same raw material is used. As polypropylene is the most significant procured raw material, its inventory and procured quantity are chosen to represent raw material inventory from procurement side.

Changes in inventory together with ability of inventory and procurement of raw material to match production of products monthly are shown in Figure 18.

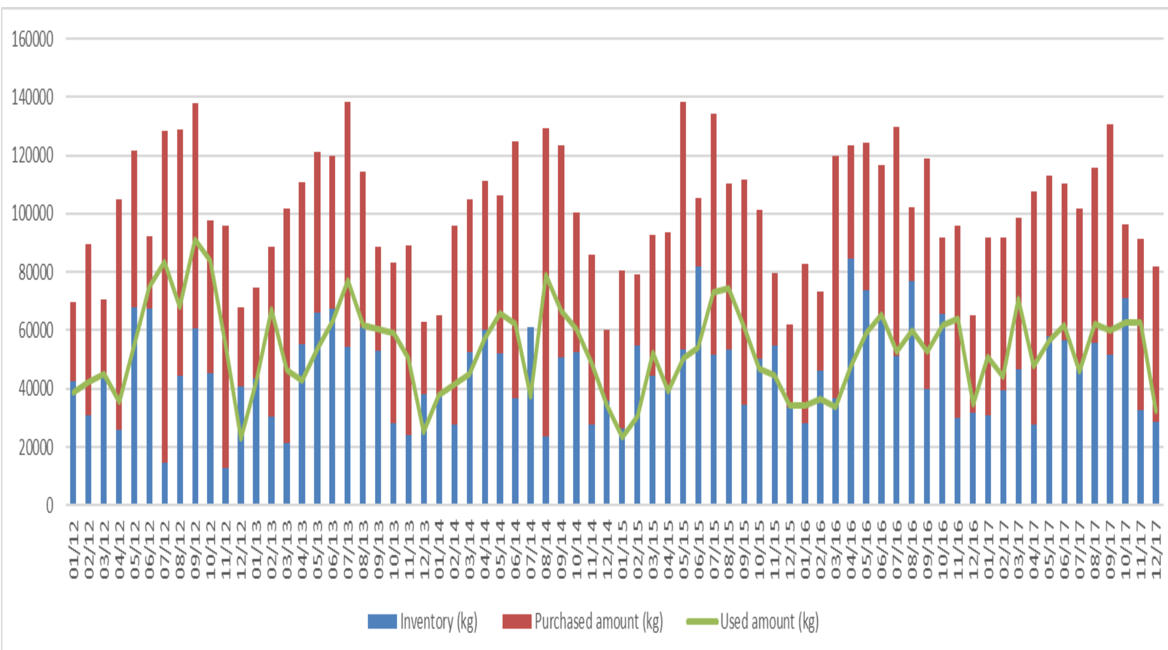

Figure 18. Comparison between levels of inventory and procurement of polypropylene together with production of products where polypropylene is used monthly from years 2012-2017.

According to Figure 18, situation of raw material inventory in 2017 is improved in comparison with previous years. In 2017 less over procurement is visible and behavior of inventory follows behavior of production, starting to drop when decrease in production takes place and grow when increase in production happens.

4.3.2 Summary of inventory analysis

According to Table 10 the most problematic inventory is Inventory 4 - end product inventory. This finding reflected in VSM is proved by Figures 14, 15. There is specific reason of high inventory in 2017 – wish to use available workforce during low-demand season. This means that anticipation inventory is formed. However, in other years (2013 – 2016) inability of inventory to follow sales, decreasing when sales grow and increasing when sales drop is caused by the fact that seasonality is not considered in reorder point calculations. Measures to reduce anticipation inventory suggested by Krajewski, Ritzman, Malhotra (2013) cannot be applied. Demand and production rates cannot be matched, because factory supervisor wants to continue to utilize available permanent workforce during low-demand season and hire less summer workers during high-demand season. According to sales manager of Finland, seasonal pricing for major customers are already used. Consequently, there is a need to search for other measures and the one suggested by Krajewski, Ritzman, Malhotra (2013) aimed to reduce safety stock instead of anticipation inventory in the form of improved demand forecast can be applied.

WIP inventory and raw material inventories are less problematic according to Table 10. Raw material inventory and WIP inventory represented by motor according to Figures 18, 17 are able to follow production of units where raw material is used and sales where motor is used, decreasing or increasing accordingly. However, in Table 10, Inventory 2 - WIP inventory is represented as average between all significant components, including motor and top part, thus even if behavior of WIP inventory represented by motor can be considered as good, behavior of WIP inventory represented by top part is questionable as there is excessive inventory in several months because of production in huge lot sizes.

5 SOLUTION

5.1 Improvement in inventory management through better forecasting

Solution which will be described further, applicable to solve end-product inventory problem. Behaviour of WIP inventory in form of procured and produced components and raw material inventory can be better controlled by another measures. Reduction in component inventory can be achieved by reduction of lot sizes. While reduction in procured inventory can be achieved by negotiating on more favourable conditions with suppliers for example changing order size what was done with motor in 2016, leading to better situation in inventory in 2017.

As can be noticed from Figures 14, 15 there is seasonality in sales. However, seasonality factor is not considered in the reorder point. Reorder point is updated every day; however, it returns moving average value functioning mostly as traditional reorder point model which is based on average and does not consider variations in demand just as Krajewski, Ritzman, Malhotra (2013) suggest. Moving average reorder point explains behaviour of inventory of end products, when in peak periods of sales inventory stays low while in minimum period of sales inventory is high in years 2013 – 2016.

According to the study conducted by Mattsson (2010) consideration of seasonal variations when calculating demand is necessary especially in case where demand is changing from one month to next month bigger than by 30%. Table 11 demonstrates that in the company, changes in demand from 1 month to another are sometimes definitely more than 30%, consequently in this case seasonality factor has to be considered.

Table 11. Changes in demand from month to month in year 2017 for products 73532 and 73482.

73532	73482
7%	114%
34%	6%

87%	33%
-30%	-56%
23%	155%
-2%	-39%
11%	53%
85%	-22%
-72%	47%
24%	-23%
-74%	-94%

Seasonality in reorder point calculation can be considered by introducing forecasted values which include seasonal and trend smoothing parameters into reorder point formula. According to the results of Babaï, Syntetos, Dallery and Nikolopoulos' (2009) study, static reorder point control policy which is often utilized in practice and dynamic reorder point control policy show same results in achieved service level. However, the considerable inventory cost reductions are obtained from the dynamic policy.

Therefore, the suggestion is to make demand part of reorder point to be based on forecasted demand instead of using traditional formula, where demand part is average and in case of the company moving average. That could be obtained by utilizing better Expak (cloud solution for better supply chain management (SCM) which is now applied in the company) possibilities, especially its function of managing sales forecast data from multiple sources and ability to make changes in forecasted values after the knowledge of significant increase or decrease in sales is obtained (Expak:2018). Contact with representative from Expak proved that it is possible to implement Holt-Winters formula in the system if client wants it. However, currently basic solution of Expak is naïve forecasting, meaning that forecast for next year is the number of last year. Naïve forecasting is wrong solution for the company with seasonal behaviour of the products.

5.1.1 Test of forecasting models

Based on Figures 14, 15 seasonality as well as trend can be observed in behaviour of sales. Consequently, the most suitable model to predict sales is Holt-Winters forecasting method. Forecast for products 73532 and 73482 is done through XLSTAT-Forecast, advanced forecasting and business statistics software in Excel (XLSTAT:2018). As in Figure 13 was proven, behaviour of each product is individual, consequently both products have different methods for calculation of systematic component: for product 73532 - seasonal additive method results in smaller forecast error while for product 73482 – seasonal multiplicative method serves better. Overall, forecast is not accurate resulting in 41% error for the product 73532 and in 37% for the product 73482, indicated by MAPE. However, even 41% and 37% forecast errors are better than situation the company has now. Currently used moving average which is applied in reorder point calculations resulted in 55% and 48% errors. The comparison between forecasted values and actual values are presented in Table 12 for product 73532.

Table 12. Comparison between forecasted values applying Holt-Winters model and actual values of previous years (2017, 2016, 2015) for product 73532.

2016	2016 forecast	Difference	Error		MAPE
70,00	78,56	-8,56	12,23		42,72
103,00	49,04	53,96	52,39		
161,00	54,61	106,39	66,08		
239,00	262,32	-23,32	9,76		
216,00	132,04	83,96	38,87		
71,00	159,24	-88,24	124,28		
129,00	191,97	-62,97	48,81		
358,00	357,14	0,86	0,24		
234,00	327,73	-93,73	40,06		
302,00	172,81	129,19	42,78		
218,00	166,32	51,68	23,71		
60,00	92,07	-32,07	53,44		

2016	2015	Difference	Error		MAPE
70,00	127,00	-57,00	81,43		58,31
103,00	40,00	63,00	61,17		
161,00	58,00	103,00	63,98		
239,00	591,00	-352,00	147,28		
216,00	45,00	171,00	79,17		
71,00	102,00	-31,00	43,66		
129,00	92,00	37,00	28,68		
358,00	361,00	-3,00	0,84		
234,00	262,00	-28,00	11,97		
302,00	114,00	188,00	62,25		
218,00	125,00	93,00	42,66		
60,00	106,00	-46,00	76,67		

2017	2017 forecast	Difference	Error		MAPE
83,00	71,00	12,00	14,46		40,29
89,00	44,53	44,47	49,96		
119,00	52,41	66,59	55,95		
222,00	254,53	-32,53	14,66		
156,00	128,74	27,26	17,47		
192,00	148,30	43,70	22,76		
189,00	183,72	5,28	2,79		
209,00	352,66	-143,66	68,74		
386,00	318,02	67,98	17,61		
110,00	174,42	-64,42	58,56		
136,00	162,84	-26,84	19,73		
35,00	84,26	-49,26	140,75		

2017	2016	Difference	Error		MAPE
83,00	70,00	13,00	15,66		52,04
89,00	103,00	-14,00	15,73		
119,00	161,00	-42,00	35,29		
222,00	239,00	-17,00	7,66		
156,00	216,00	-60,00	38,46		
192,00	71,00	121,00	63,02		
189,00	129,00	60,00	31,75		
209,00	358,00	-149,00	71,29		
386,00	234,00	152,00	39,38		
110,00	302,00	-192,00	174,55		
136,00	218,00	-82,00	60,29		
35,00	60,00	-25,00	71,43		

Moreover, qualitative forecasting can also help to facilitate improvement in inventory management. According to experiments of Plinere and Borisov (2015), timely reaction to changes in the environment can propose better results in inventory management. Possibilities to meet real demand improve if production planner will combine qualitative forecast with the quantitatively forecasted demand and make modifications in future orders if needed. Consequently, it is important that sales department informs production department about actions which might cause decrease or increase in demand in future for the products and share this information regularly when it is available in form of long and short-term forecasts. Suggested information sharing is demonstrated in Figure 19.

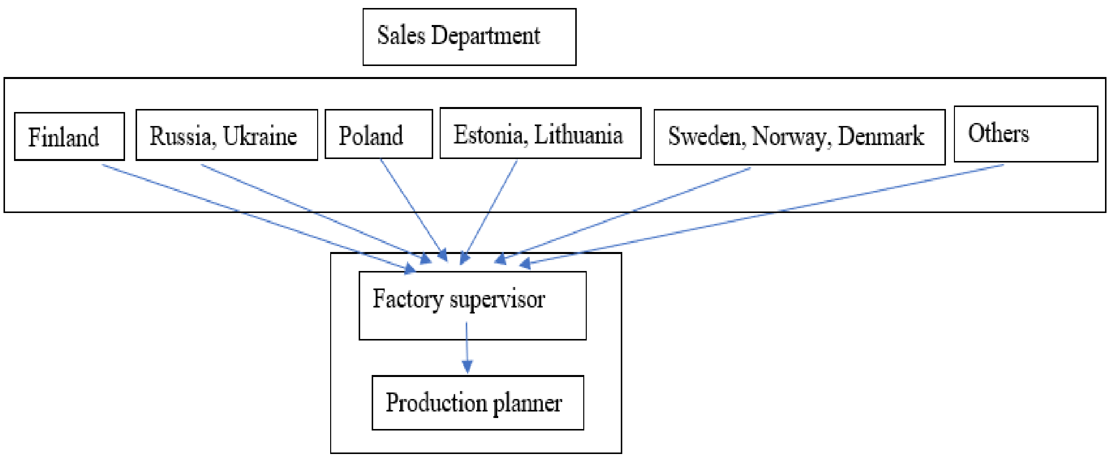

Figure 19. Improved information flow between sales and production departments in form of long-term and short-term qualitative forecasts.

Utilization of both qualitative and quantitative forecasting methods will result in more accurate demand forecasting. In turn that will lead to more efficient decisions for the planned production, as replenishment algorithm will use forecasting results instead of moving average and information on customer's preferences in short term perspective will be available, what will allow to lower inventory levels and costs of maintaining inventory (Kot &Grondys:2014).

5.2 Improvement in inventory management through better use of inventory control systems

First suggested solution might face several problems. Firstly, even if representative of Expak said that it is possible to implement Holt-Winters model in the system, in fact it might not be easy. Secondly, anticipation inventory is planned to be used in future anyway. Consequently, precise numbers in reorder point calculation facilitated by Holt-Winters model might not be needed. In this case, the author of the thesis would like to suggest easier option. Seasonality has to be taken into account. It can be done by dividing sales of end-products of last year in two categories: low season period and high season period. Consequently, reorder point will be still moving average, however moving average for two seasons. This technique will make reorder point lower in low season and higher in high season. Anticipation inventory will be still produced in winter period (low season), however less than when reorder point is average.

Qualitative forecasting method is still recommended even in second solution, as it will allow production planner to react on time. Available information will serve as signal for him to speed up or slow down production of particular product.

6 CONCLUSION

This is inductive study, which has features of exploratory, descriptive and explanatory single case study, utilizing mix of qualitative and quantitative research methods in data collection and data analysis. Value Stream Map is powerful visual Lean tool, which helps to detect wastes within companies. Traditional VSM was applied in the study, providing the answer to the first research question. The second research question was answered applying theories of inventory management and demand forecasting which are not standard methods to reduce wastes identified through VSM.

1. What types of waste can be identified through implementation of traditional VSM?

Wastes which can be identified depend on what type of VSM is used. According to theory standard VSM can be added with: Process Activity Mapping, Supply Chain Response Matrix, Production Variety Funnel, Quality Filter Mapping, Demand Amplification Mapping, Value Analysis Time Profile and/ or Decision Point Analysis (Hines & Rich 1997; Hines & Taylor 2000). In this case all types of waste can be detected in a company. However, in this study traditional VSM was used. With help of traditional VSM, it was possible to identify wastes in form of overproduction and inventory. Waste in form of defects could be also observed through traditional VSM, however it was not possible because collection of relevant data needed for analysis of number of defects just has started in the company. Consequently, can be concluded that 2 types of waste out of 8 were identified through implementation of standard VSM. Out of 2 identified wastes - waste in form of inventory was investigated further.

2.How to achieve reduction in identified waste?

Theory suggests standard solutions to gain reduction of wastes: establishment of continuous flow, supermarkets, levelling, shortening of changeover time. However, in this thesis solution was different from theory suggestions. According to Kwasala, Shahrukh (2001) standard solutions are also limitation of VSM, in addition according to Khalid, Hashim, Salleh (2014), VSM is only a snapshot of what is happening on the shop floor.

Considering limitations, instead of suggesting and implementing basic practices, the study goes deeper into investigation of observed waste – excessive inventory. The aim was to analyse behaviour of inventories not just at specific time as VSM suggested but in broad time range from years 2012 to 2017. Consequently, analysis showed that VSM tool revealed right results according to which end-product inventory is the most problematic, being the reason of high lead time. WIP and raw material inventories were less problematic according to VSM, what is partly right on WIP inventory and totally right on raw material inventory. WIP inventory was represented by procured part – motor and produced part – top part of roof fan. WIP of procured part can match sales, decreasing and increasing together with drop and growth in sales. However, WIP of produced top part does not match production of end-product, as top part is produced in huge lot sizes resulting in huge inventories. Suggested improvement for WIP of top part is reduction of lot sizes.

The main solution was developed for end-product inventory studying inventory management practices and forecasting methods. End-product inventory in 2017 as well as in 2012 is higher than in other years due to specific reasons – utilization of available workforce during low-demand season in 2017 and confusion in names of products what led to “better to produce more just in case” thinking, in 2012. Inventory discovered in 2017 is anticipation inventory. Measures for reduction of anticipation inventory cannot be applied. Firstly, demand and production rates cannot be matched, because factory supervisor wants to continue to utilize available permanent workforce during low-demand season and hire less summer workers during high-demand season. Secondly, seasonal pricing and campaigns are already used.

However, measures aimed to reduce safety stock instead of anticipation inventory in the form of improved demand forecast can be applied in this situation.

The problem of previous years (2013-2016) is that inventory is too high when sales are low but when sales are high inventory is low. This situation is caused by the fact that seasonality factor, discovered by observing behaviour of sales, is not considered in reorder point calculations. Just as according to theory, reorder point is calculated based on average demand and in case of the company it is based on moving average. Studies show that there are seasonality and trend in sales of end-products, consequently seasonality and trend have to be taken into account in demand part of reorder point. Solution is to perform forecasting based on Holt-Winters model and utilize forecasted numbers in reorder point calculations. According to calculations, numbers forecasted by Holt-Winters model are better than currently utilized moving average technique at least by 10%. Technically, solution is possible to implement through Expak system which company uses now. In addition, qualitative forecast can help production planner to meet real demand, decreasing or increasing produced amount of end-products when needed.

In case if suggested solution is technically difficult to perform, there is also another solution. Sales can be splited into two seasons: high season and low season, which averages will be used in reorder point calculations. It will allow to make anticipation inventory lower in winter (low season) and higher in summer (high season). Qualitative forecasting is still highly recommended even in second solution. The aim of suggested solutions is to establish better control over anticipation inventory and possibly to reduce it.

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APPENDICIES

APPENDIX I: Questions

Session1:

1. Products which are demanded the most and pass through the longest production way?
2. Sales of the selected products 2016-2017?
3. Structure of selected products?
4. Processes needed to produce products?
5. Number of working days per month; working hours together with lunch time and breaks?
6. Frequency of orders from customers?
7. Delivery time to customer?
8. Frequency of orders from suppliers?
9. Delivery time from supplier?
10. Frequency of production plan communication?
11. Number of operators per production process?
12. Cycle time of the processes?
13. Changeover time/setup time of the processes?
14. Defects rate?
15. Uptime?
16. Batch size/lot size of the processes?
17. Places and types of inventories? What are re-order points of the most significant components and raw materials found in each inventory? What other products besides selected ones use chosen components and raw materials?

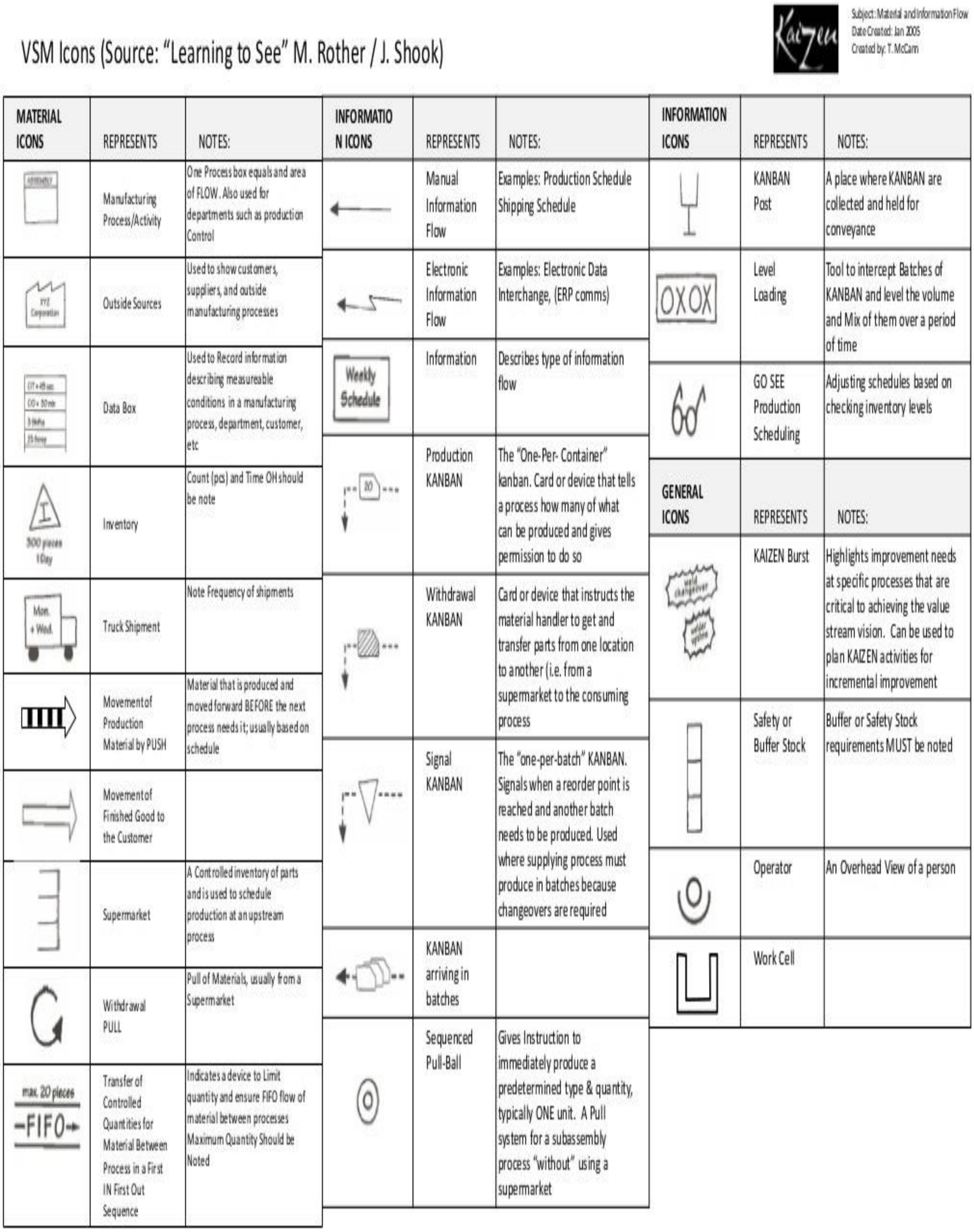
Session 2:

1. Comments on identified problems. Which problem is relevant (what must be considered further)?

Session 3:

1. Annual sales of selected products monthly years 2012-2017?
2. Beginning inventory monthly years 2012-2017: selected products, top part, motor, raw material?
3. Produced amount monthly years 2012-2017: selected products, top part, products where top part is used?
4. Sales monthly years 2012-2017: selected products, products where motor is used?
5. Procured amount monthly years 2012-2017: motors, raw material?
6. Used amount of raw material monthly?
7. What are the reasons for high level of finished products inventories in years 2012 and 2017?
8. How re-order point is calculated in the company?
9. Why in years 2017 and 2012 level of inventory is very high?
10. Is information about future demand gained from customers communicated further to production?

APPENDIX II: VSM icons (Rother&Shook: 2003)



VSM Icons (Source: "Learning to See" M. Rother / J. Shook)

Subject: Material and Information Flow
Date Created: Jan 2005
Created by: T. McCam

MATERIAL ICONS	REPRESENTS	NOTES:
	Manufacturing Process/Activity	One Process box equals and area of FLOW. Also used for departments such as production Control
	Outside Sources	Used to show customers, suppliers, and outside manufacturing processes
	Data Box	Used to Record information describing measureable conditions in a manufacturing process, department, customer, etc
	Inventory	Count (pcs) and Time OH should be note
	Truck Shipment	Note Frequency of shipments
	Movement of Production Material by PUSH	Material that is produced and moved forward BEFORE the next process needs it; usually based on schedule
	Movement of Finished Good to the Customer	
	Supermarket	A Controlled inventory of parts and is used to schedule production at an upstream process
	Withdrawal PULL	Pull of Materials, usually from a Supermarket
max. 20 pieces –FIFO→	Transfer of Controlled Quantities for Material Between Process in a First IN First Out Sequence	Indicates a device to Limit quantity and ensure FIFO flow of material between processes Maximum Quantity Should be Noted

INFORMATION ICONS	REPRESENTS	NOTES:
	Manual Information Flow	Examples: Production Schedule Shipping Schedule
	Electronic Information Flow	Examples: Electronic Data Interchange, (ERP comms)
Weekly Schedule	Information	Describes type of information flow
	Production KANBAN	The "One-Per- Container" kanban. Card or device that tells a process how many of what can be produced and gives permission to do so
	Withdrawal KANBAN	Card or device that instructs the material handler to get and transfer parts from one location to another (i.e. from a supermarket to the consuming process
	Signal KANBAN	The "one-per-batch" KANBAN. Signals when a reorder point is reached and another batch needs to be produced. Used where supplying process must produce in batches because changeovers are required
	KANBAN arriving in batches	
	Sequenced Pull-Ball	Gives Instruction to immediately produce a predetermined type & quantity, typically ONE unit. A Pull system for a subassembly process "without" using a supermarket

INFORMATION ICONS	REPRESENTS	NOTES:
	KANBAN Post	A place where KANBAN are collected and held for conveyance
OXOX	Level Loading	Tool to intercept Batches of KANBAN and level the volume and Mix of them over a period of time
	GO SEE Production Scheduling	Adjusting schedules based on checking inventory levels

GENERAL ICONS	REPRESENTS	NOTES:
	KAIZEN Burst	Highlights improvement needs at specific processes that are critical to achieving the value stream vision. Can be used to plan KAIZEN activities for incremental improvement
	Safety or Buffer Stock	Buffer or Safety Stock requirements MUST be noted
	Operator	An Overhead View of a person
	Work Cell	