JÖNKÖPING UNIVERSITY
School of Engineering

COST OPTIMIZATION IN PRODUCTION SYSTEMS

USING LEAN MANUFACTURING

PAPER WITHIN *Production Systems*
AUTHOR: *Amarnath Dhayanithi, Deepak Sureshkumar*
TUTOR:
JÖNKÖPING Month 2019

This exam work has been carried out at the School of Engineering in Jönköping in the subject area Production system with a specialization in production development and management. The work is a part of the Master of Science program. The authors take full responsibility for opinions, conclusions and findings presented.

The authors take full responsibility for opinions, conclusions, and findings presented

Examiner: Kerstin Johansen

Supervisor: Mahmood Reza Khabbazi

Scope: 30 credits (second cycle)

Date:

Abstract

In the era of globalization, every company is trying its best to sustain its company's name and their product in its respective market.

The overreach goal of the thesis to optimize the cost in the production system using lean manufacturing. To attain the primary goal of the thesis, three layered approach has been carried out.

Firstly, the non-value-added activities in the shop floor has been identified. The tools like VSM and spaghetti diagram is used to identify the non-value-added activities

Secondly, the lead time of a particular product has been calculated for a particular product. The lean tools like JIT,5s, TQM, TPM has been used to reduce the lead time. TQM is used to identify the quality issues, TPM is used to identify the maintenance problems and JIT &5s is used to identify the problems in tool arrangement and delivery of the raw materials.

The last part of the thesis is to measure the cost-effectiveness by implementing lean manufacturing to produce a particular product family. Tools like Activity based costing is used to allocate the cost involved in the various activities that can be measured by the cost drivers and cost pool. To measure the performance of the production system OEE is used in this thesis.

Keywords

Cost Optimization, Lean tools, Value Stream Mapping, Supply chain Management.

Contents

ABSTRACT 1

1 Introduction 6

1.1 BACKGROUND 6

1.2 PROBLEM DESCRIPTION 7

1.3 PURPOSE ANDRESEARCH QUESTIONS 7

1.4 DELIMITATIONS 8

1.5 OUTLINE 8

2 Theoretical background 9

2.1 SUPPLY CHAIN MANAGEMENT 9

2.2 LEAN 9

2.3 TOYOTA PRODUCTION SYSTEMS: 10

2.3.1 Transport 10
2.3.2 Inventory 11
2.3.3 Motion 11
2.3.4 Waiting 11
2.3.5 Over Processing 11
2.3.6 Over Production 11
2.3.7 Defect 11

2.4 JUST IN TIME 11

2.5 CELLULAR MANUFACTURING 13

2.6 TOTAL PRODUCTIVE MAINTENANCE 13

2.6.1 EIGHT PILLARS OF TPM 14

2.7 TOTAL QUALITY MANAGEMENT 16

2.8 OVERALL EQUIPMENT EFFECTIVENESS 17

2.9 VALUE STREAM MAPPING 18

2.10 ACTIVITY BASED COSTING 21

2.11 SPAGHETTI 22

3 Method and implementation 23

3.1 STRUCTURAL METHOD RELEVANT TO RESEARCH QUESTION 23

3.1.1 Literature review 23
3.1.2 Relevant data and finding appropriate flow 23
3.1.3 Analyzing product flow 25
3.1.4 Recognizing the challenges within the production line 25
3.1.5 Additoinal data collection 23
3.1. 6 Evaluating the cost of a product 23

3.2 CASE COMPANY: 25

3.3 RESEARCH METHOD 25

3.3.1 Case study 24

3.3.2 Data collection 24
3.3.2.1Interviews 24
3.3.2.2 Exploratpry interviews 24
3.3.2.3 Explanatory interviews 24
3.3.2.4 Observations 24
3.3.2.5 Internal Documentation 24

4 Findings and analysis 28

4.1 PRODUCT FLOW 28

4.1.1 Hall1 28
4.1.2 Hall2 30
4.1.3 Hall3 30
4.1.4 Hall6 31
4.1.5 Buffer station 32
4.1.6 Hall5 32

4.2 ANALYSIS OF THE SIDE PANEL AND ITS COST 35

4.2.1 Quality Defective Products 35
4.2.2 Machine Maintenance 36
4.2.3 Unnecessary Transportation 36

4.3PERFORMANCE OF THE PRODUCTION SYSTEM 36

4. 4 COST OF SIDE PANEL USING ABC 37

5 Discussion and conclusions 40

5.1 DISCUSSION OF METHOD 40

5.2 DISCUSSION OF FINDINGS 40

6 Conclusions 43

7 References 44

8 Appendices 47

8.1 INTERVIEW QUESTIONS 47

8.2 ABBERIVATIONS 48

8.3 CURRENT STATE MAP 49

8.4 SPAGHETTI DIAGRAM 50

8.5 SHOP FLOOR LAYOUT 51

List of Figures

figure 1 Leanness Measurement using PDCA Method (Anvari, Norzima , & Omid , 2014).....9
Figure 2 Just In time production environment (Huq & William E, 1996). 12
Figure 3 Example of a Balanced Cellular Manufacturing System (Metternich, Sven , & Stefan , 2013).....13
Figure 4 Key Elements of the TPM (Chan , Lau , Ip , Chan , & Kong S, 2005). 14
Figure 5 TPM PILLARS (Shinde & Ramjee , 2018) 15
Figure 6 The OEE Formulation and the six losses (Batumalay k & Santhapparaj, 2009). 18
Figure 7 VSM Implementation Phases (Tyagi, Alok , Xianming , & Kai , 2015).....19
Figure 8 Current State Map Icons (Braglia, Gionata , & Francesco , 2006). 20
Figure 9 Future State Map Icons (Braglia, Gionata , & Francesco , 2006). 20
Figure 10 Spaghetti diagram (SENDERSKÁ, Albert , & Štefan , 2017).....22
Figure 11 Raw materials in Hall 1.....29
Figure 12 Punching Process in Hall 2 30
Figure 13 Fladder Machine in Hall 3 31
Figure 14 Bending Process in Hall 6 31
Figure 15 Håger process in hall 6.....32
Figure 16 Outbound Area in Hall 5.....34

List Of Table

Table 1 Comparison between Traditional cost system and activity-based cost (Hamide & Yusuf , 2014). 20

List of Equations.

Equation 1 Overall Equipment Effectiveness 17
Equation 2 Cost Calculation..... 21

1 Introduction

The purpose of this chapter is to explain why this thesis has been initiated and present an overview for the reader. The aim is to z analyze the present product flow and improve cost efficiency in the following subchapters. The background helps to define the existence of the problem within the company, while the problem is further elucidated in the second subchapter. These subchapters help to provide an outline of the purpose and research question. The delimitations are followed up and outline which is presented to give an overview structure to the rest of the thesis.

1.1 Background

During the past decades, global competitiveness has been increased drastically. Many manufacturing companies are trying to implement lean manufacturing and its tools to achieve their goals, vision, and mission. In order to be more competitive many companies, adopt new technologies like lean manufacturing (Shah & Ward, Lean manufacturing: context, practice bundles, and performance, 2003)

The cost involved in the manufacturing sectors or production industries plays a major role and have a huge impact on the problems like production, consumption, price, redundancy, intensification, and economic growth (Zaharia & Bordeianu, 2018).The lack of cost management in the company affects the profits and business process. "Cost is the value accepted by the buyer for buying a specific good or is the sum of all aggregate values of a product since its acquisition until it reaches the marketing phase" (Mello & Santos, 2016).

Lean production is frequently used as a substitute for Toyota Production System (TPS), which itself evolved from Taiichi Ohno's experiments and it's been there over the past three decades at Toyota Motor Company (Shah & Ward, Defining and developing measures of lean production, 2007).Lean manufacturing focuses on the elimination of wastes from an organization's operations through a set of alternative work practices where the operations are synchronized together to produce products and services at the rate of demand ((Mark)Yang, PaulHong, & B.Mod, 2011).lead time The programmed of lean improvement provides a streamlined flow of information and materials to achieve cost competitiveness (Hong & Leffakis, 2017). In an effort to improve, minimize unwanted operation and maintenance costs, the Total Preventive Maintenance program has played a major role to increase equipment availability and hence reducing the need for further investments (Ng K. , C.P.Lim, Chon, & G.G.G.Goh, 2013). The important tool that is used to Total productive maintenance and measures the effectiveness of a single and continuous machine is Overall Equipment effectiveness (Wudhikarn, 2016). Total quality management (TQM) is the application of quantitative methods and human resources that improve all processes within an organization and exceed both current and future customer needs (Yu, Park, & Hong, 2017). Each firm's optimum level of TQM adoption will be the one that allows the firm to reduce its total transaction costs, or in other words the level at which the firm can create the most profit (García-Bernal & García-Casarejos, 2014).Lean has developed beyond its original use on the shop floor of vehicle manufacturers to other functional areas within organizations, to other manufacturers and to non-manufacturing organizations (Samuel, Found, & Williams, 2015).

Operating costs that relate directly to the production techniques like Activity-based costing, lean accounting, and other tools are used to obtain the actual process information. The role of activity-based cost is to identify the real cost of activities

involved in the operation, the role of value stream mapping is to identify the waste activities and the implementation of lean tools is to eliminate the identified waste (Guimarães, Medeiros, Santana, & Pereira, 2015) . Cost reduction in the process can be achieved by new process innovation, which consists of lean production initiatives, inventory optimization and quality improvements . (Fernando Bernstein, 2009)Lean tool purpose is to uncover the wastes in the supply and production process by separating value-adding and non-value-adding steps first and then reduce or eliminate non-value added steps (Chowdhury, Shahriar, Hossen, & Mahmud, 2016) .To improve productivity, it is essential to identify the production waste and eliminate waste by applying the lean methodology in the production lines (Ng K. C., C.P.Lim, Chong, & Goh, 2016). Transferring information about the value stream to a 'map', which represents either the current or future state of the manufacturing system is called as Value stream mapping (Chen, Li, & Shaddy, 2010).

1.2 Problem Description

Due to fluctuations in customer buying patterns resulting in product that has low demand can be more , but its future demand may still be large enough (Matthew Lindsey, 2009). Overproduction causes additional handling, inspecting, counting and storing costs of those not yet needed products and also defects remain hidden in the inventory queues until the downstream process finally uses the parts. However, it is important to identify the non-value adding waste in the product-based process-driven value streams waste before eliminating (Gibbons, Kennedy, Burgess, & Godfrey, 2012).

The focal company appointed the researchers to conduct a study to optimize cost for the future demand product. Before giving the suggestion, we tried to identify the non-value-added activities that prevailed in the company. Then based on the non-value-added activities which have been identified by the researchers, valid reasons have been given to the focal company for the existence of the non-value-added activities and increase lead time for the product. To achieve the primary goal of this thesis qualitative and quantitative method has been carried out to show them the cost involved in the various activities.

1.3 Purpose and Research questions

The purpose of this master thesis is to find value and non-value-added time in the production line for a single product family with the help of Value stream mapping. Reduce the production cost by eliminating the unnecessary waste that prevails in the production line. To attain this purpose three research questions have been formulated:

RQ1. What are the non-value added activities that existed in the process to produce a particular product?

RQ2. How the lead time be reduced for a particular product?

RQ3. How cost-effectiveness can be obtained by implementing lean manufacturing to produce a particular product family?

1.4 Delimitations

When the company produces many products, it is essential to consider a holistic perspective in order to avoid sub-optimization. But, in this thesis only one product family has been studied and while other products have different characteristics.

The study is conducted for a side panel for computer cabinet and suggestion for cost optimization is given to that particular product. Due to other flow of materials in the same assembly line, the authenticity of the result can vary. The time frame allocated is 20 weeks so short-term performance measurement and short-term decisions are only considered, but not the long-term perspective. The case study is carried out in a single case company so the results may be varied from one company to another. Activity-based Costing includes all the costs involved in the shop floor, so external factors like transportation costs are excluded as is the Return on Investment (ROI). The inventories used for multiple products on the shop floor, so the cost calculated is approximate to some extent.

1.5 Outline

To help the reader the thesis is structured into five main chapters

Chapter 1 / Introduction: This chapter gives a brief presentation of the thesis background to the subject areas, and further elucidated a description of the problem phenomena to be explored. Different aspects such as purpose, research questions, delimitations are presented.

Chapter 2/ Theoretical background: This chapter gives an overview of the literature and theoretical background of the subject which is investigated. The theoretical framework is presented with an explanation of lean tools and different types of financial accounting.

Chapter 3/ Method and implementation: This chapter explains how the study was structured, conducted and what type of data collection techniques were practiced.

Chapter 4 /Findings and analysis: Within this chapter, the findings from the theoretical background and case study will be described briefly. Then the findings will be discussed, compared, analyzed and organized.

Chapter 5 / Discussion and conclusions: In this last chapter, discussion and conclusion for further research on lean implementation for cost optimization will be presented. The study related to the reliability and validity of this thesis will be discussed.

1 Theoretical background

2.1 Supply chain Management

The customer requirements are constantly changing and become highly unpredictable which forces SC(supply chain) to respond faster and with more effectiveness and efficiency. The main objective of SCM is to reduce the total cost simultaneously satisfying the customer needs without any compromise in service. The main aims in the SCM of an organization is to coordinate the upstream flow of incoming materials and services, to cope with uncertainties that may appear without generating excess inventories but the downside is the disturbances that may occur in the operational SC, leading to a change in the planned course of events **(**Barros, Machado, & Machado, 2013). Inaccurate forecasting, long lead times, delivery delays, incomplete shipment, batch ordering and fluctuations in prices are the factors that contribute to SC uncertainty. The cost reduction applicable not only in the shop floor activities it is applicable to the supply chain activities as well (Christopher & John , 2005). Many companies cost lies out their boundaries. So it is important to consider the supply chain activities. "**Collaborative planning Forecasting and Replenishment**" is a method used to share the knowledge and information with the supplier so the unnecessary waste/ cost is eliminated or reduced (Christopher & John , 2005).

2.2 Lean

The Term Lean was first Introduced by (Krafcik, 1998) to Specify Toyota's Production System. (TPS). Lean production is the process of eliminating waste or balancing the flow of the process. The most successful adoption of the lean concept is Toyota's Production System. The manufacturing systems that implemented lean concepts have benefits such as high level of efficiency, competitiveness at low cost, high level of productivity, increase speed of delivery, minimum stock levels and optimum quality (Pakdil & Karen, 2014). The selection of the proper lean tool is the challenging part faced by the industries. This process determines the success or failure of the lean manufacturing systems. The success of implementing proper techniques can be interlinked, relate to the level of leanness. A PDCA method is used to measure the level of leanness. Fig 1 shows the illustration of PDCA (Anvari, Norzima , & Omid , 2014).

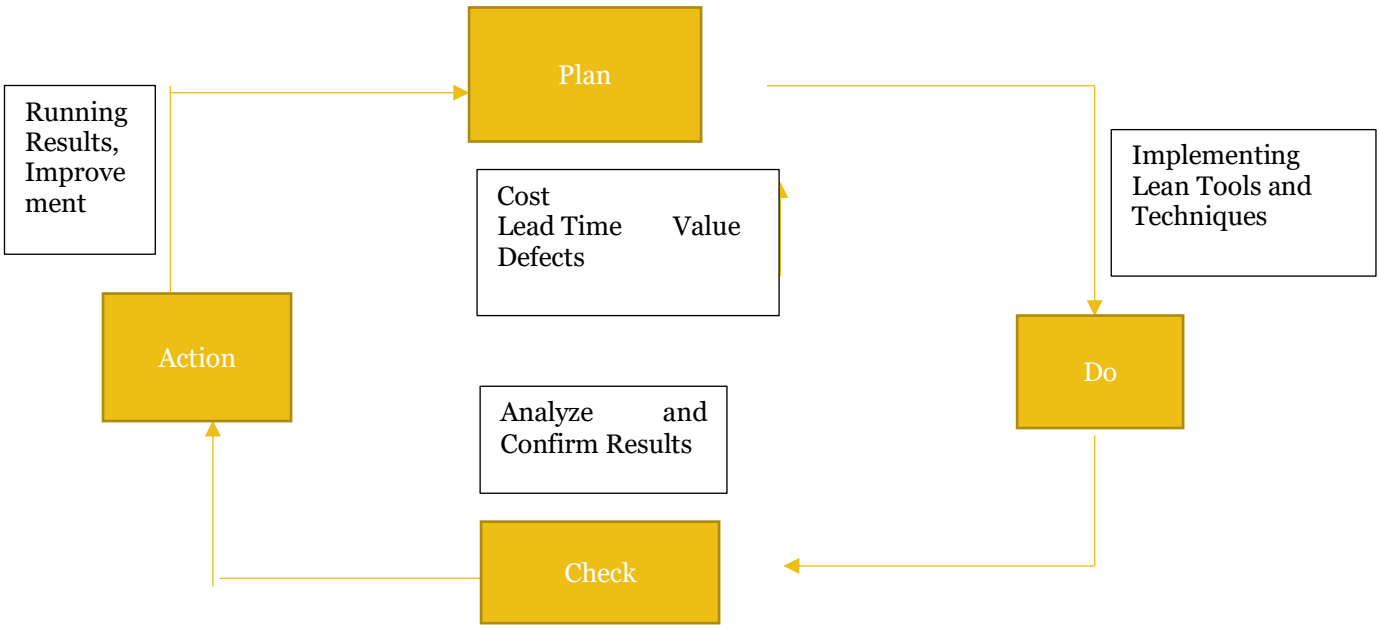


Figure 1 Leanness Measurement using PDCA Method (Anvari, Norzima , & Omid , 2014)

Lean manufacturing is a philosophy of management, involving the process of continuous elimination of waste, to sustain the company in the rapid globalization market. After the success of lean manufacturing, lean manufacturing techniques are later implemented in North America and European countries. It is not achieved by reducing the workforce or labor force or increasing the workload of an employee. The employee commitment and involvement to implement the lean in the production system. "lean is the removal of all unnecessary time, actions and causes of errors from raw materials to be finished product, from order to delivery, and from idea to implementation." (Ingaldi & Marta , 2014)
Lean manufacturing is a methodology used in the organization to improve the quality of work done by reducing the loss that occurred in the system. The lean approach is to reduce or eliminate the activities that do not bring any value to the product (Gavriluţă, 2019).
According to (Uhrin, Sebastian , & José , 2017).Lean production refers to the "A set of integrated socio-technical principles with the aim of minimizing internal and external system variability to the lowest extent. The most characteristics practices of lean production can be classified into the following classification

1. Just-In-Time (JIT) Production,
2. Cellular Manufacturing,
3. Total Productive Maintenance (TPM) and
4. Total Quality Management. (Uhrin, Sebastian , & José , 2017)

2.3 TOYOTA PRODUCTION SYSTEMS:

The success of the Toyota production system attracted many firms all around the world, and they implemented the TPS in their firms but only a few have been achieving success as Toyota achieved. The Major Theme of the Toyota production system is to set practices on cycle time, quality, cost, and delivery dimensions of manufacturing performance. Lean philosophy and TPS lead to achieving activities like eliminating waste, rooting out defects and reducing the lead time (Jayaram, Ajay , & Mariana , 2010). The Toyota production system is known as the most popular production concept. TPS is the philosophy of elimination of waste which finally resulted in a Lean Concept. Even though Just in Time is always related to the TPS, the very basic concept is the 'reduction of cost through elimination of waste' (Thun, Martin , & André , 2010). By implementing the Toyota Production system concepts companies producing the products efficiently and has a competitive advantage in the global market. The seven types of wastes are identified, which are

1. Transport
2. Inventory
3. Motion
4. Waiting
5. Over-Processing
6. Over-Production
7. Defects

2.3.1 Transport

The transport waste is unnecessary movement of the finished goods, raw materials also work in progress (Hill, 2018). Transportation is an important activity but does not add any value to the product which can't be neglected. Transportation is the process of material movement from one workstation to the other either by the operator or other sources(conveyor, trucks etc.) (Adesta & D. Agusman, 2018). The Movement of

information from one place to the place to carry out the desired task (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.2 Inventory

The excess of raw materials which result in inventory waste directly result to works-in-progress, or finished goods that exceed the demand (Hill, 2018). Unnecessary inventory excess amount of material inventory, Work in Progress in-between the workstation (Adesta & D. Agusman, 2018). The information exceeds then the required amount of information (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.3 Motion

The motion waste relates to the unnecessary movement of the people that do not add any value to the product (Hill, 2018). The motion is an unwanted movement of the operator which does not add any value to the product and also increases the lead time of the process (Adesta & D. Agusman, 2018). Movement of the people to have the required information access to finish the process (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.4 Waiting

The waiting refers to the stoppage of the unfinished products which waits in the production line to move to the next stage of the production (Hill, 2018). Waiting is the time interval in which the operator does not use the time to add value to the product (Adesta & D. Agusman, 2018). The waiting for the processor to get the information required to finish the process (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.5 Over Processing

This kind of waste is hard to detect and eliminate. This waste is created when there is excess processing for the final product than the customers' requirement (Hill, 2018). This type of waste happens when the Standard operating procedure is not followed and also increase the probability of producing damaged products (Adesta & D. Agusman, 2018). The information is processing is exceeded to achieve the desired output (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.6 Over Production

This waste involves the production of the product before the product is needed. It causes excess inventory and creates inefficiency in the production system (Hill, 2018). This waste is the excess production of the schedule (Adesta & D. Agusman, 2018). The creating excess of information than the required information (Tyagi, Alok , Xianming , & Kai , 2015).

2.3.7 Defect

The produced product which required rework or scrap is called the defects.
Scrap is a product that cannot carry any rework to achieve the desired outcome to meet the customers' requirements (Hill, 2018). The incompatible with the required customer requirement is called as the defects or defective products (Adesta & D. Agusman, 2018). Mistakes occurred in the activities than create a rework situation to finish the product (Tyagi, Alok , Xianming , & Kai , 2015).

2.4 Just In Time

Just In time (JIT) is a lean practice which has a major objective to produce or deliver the right part in the right place at the right time (Kant, L. N, & Vijay ,

2014).If the excess amount of products are produced it is considered as a waste, since there is no value or profit to the company. Inventory is an important factor that directly affects the other aspects of the manufacturing system as well, like occupying the floor space, it can affect the lead time and efficiency. This can be controlled by one specific technique that is used in the lean manufacturing system is called JIT(Just-in-Time).

JIT allows the firm to react contemporaneously to fluctuating demand and also adjusts inventory holdings with all information about the present state of the economy and receives new purchases before current-period production starts (Gao, October 2018).This can be done with a better flow of communication between the supplier and the customer. It's always essential for the supplier to be proactive to prevent the absurd stop in the production line when there is a fluctuating demand. By doing this, increased quality and efficiency can be obtained within the manufacturing system.

Pull System methodology follows each stage production, at both the macro and micro levels. The demand and inventory between the workstations are documented. the Japanese term for this documentation is called Kanban which is Production Kanban and Withdrawal Kanban (Huq & William E, 1996).

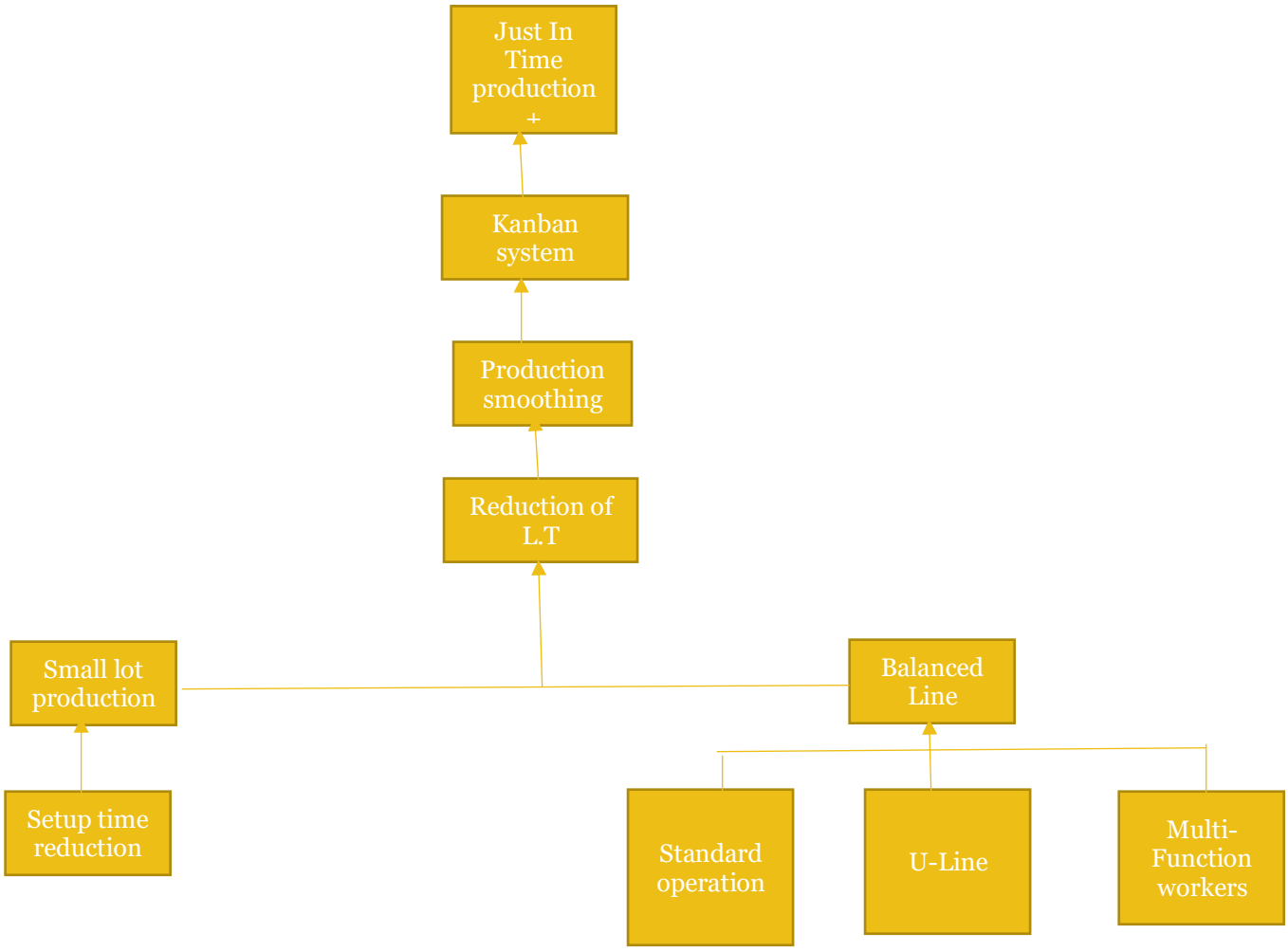


Figure 2 Just In time production environment (Huq & William E, 1996).

2.5 Cellular Manufacturing

Cellular Manufacturing is also called as group technology (GT). In manufacturing, the grouping of similar workstations and the formation of the cell could be processed in a machine cell. By implementing the cellular manufacturing, the company has advantages like reducing the setup time and reduce the material handling cost (Kant, L. N, & Vijay , 2014). The term cellular manufacturing implies the process of grouping dissimilar equipment to manufacture the family of the parts (Metternich, Sven , & Stefan , 2013). The cellular manufacturing has the following elements,

1. Grouping of parting families,
2. Cell Formation and layout
3. Line Balancing
4. Improvements to job shop Production (Metternich, Sven , & Stefan , 2013).

Cell manufacturing includes various technologies to finish the production process and deliver finished products. An Example of balanced cellular Manufacturing systems is shown in the figure2.

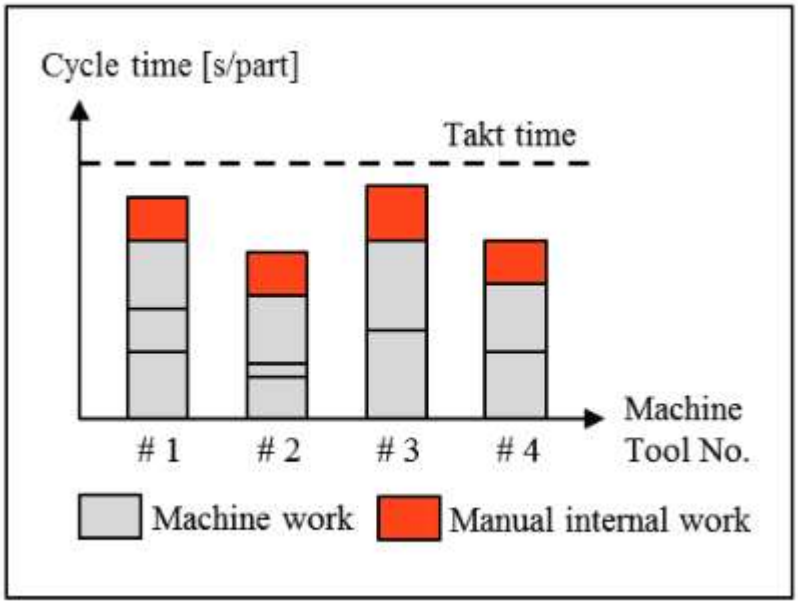


Figure 3 Example of a Balanced Cellular Manufacturing System (Metternich, Sven , & Stefan , 2013)

2.6 Total Productive Maintenance

The term Total Productive Maintenance (TPM) is a holistic approach to machine maintenances that attempts to achieve a perfect production process. The Advantages achieved using TPM in the manufacturing sector are fewer breakdowns, stops, and defects which also reduce the cost involved in the production process. The TPM increases the machine or equipment life and eliminates unnecessary stoppage or breakdowns (Agustiady, Tina , & Elizabeth , 2018). The TPM methodology is to increase the availability of the existing system in the production line, therefore eliminating further capital investment (Chan , Lau , Ip , Chan , & Kong S, 2005). TPM includes the following elements,

1. The aim of TPM is to maximize equipment effectiveness
2. TPM establishes a thorough system of PM for the equipment's entire life span,
3. TPM is implemented in all departments in the organization
4. TPM involves all the employees from the top management to shop floor in the organization.
5. TPM is PM through "Motivation Management" involving small activities (Chan , Lau , Ip , Chan , & Kong S, 2005).

The key elements of the TPM are shown in figure 3. The system efficiency is reduced by the operators, not managers or systems.

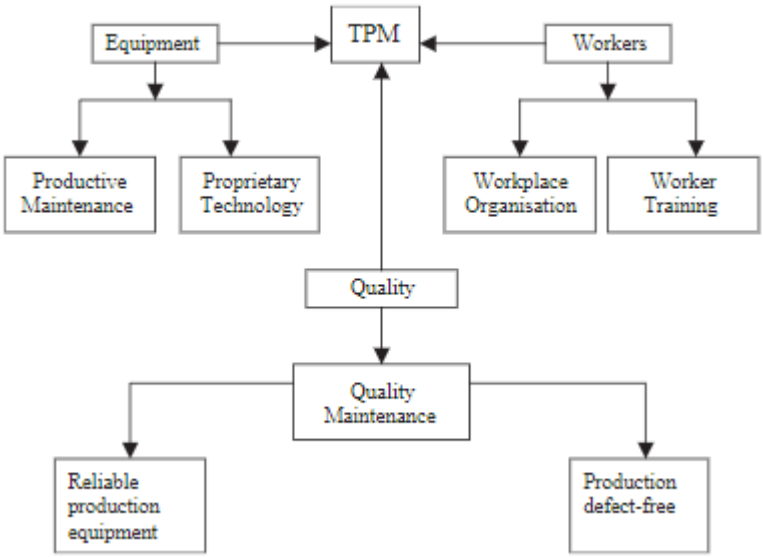


Figure 4 Key Elements of the TPM (Chan , Lau , Ip , Chan , & Kong S, 2005) .

2.6.1 EIGHT PILLARS OF TPM

TPM is based on eight pillars with the base of 5s. The objective of 5s is to create a clean and well-organized work environment (Shinde & Ramjee , 2018).

5S:

In the Lean manufacturing 5S method is the basic concept of lean. The goal of 5S is to create and maintain a well-organized, clean, highly effective and high-quality workplace (Filip & Marascu, 2015). The 5S has the following implications are

- Sort (Seiri): separate or eliminate the unnecessary things by the necessary tools (Filip & Marascu, 2015).
- Set in Order (Seiton): According to the usage the items are placed properly in the logical order and store them with a well-established location (Filip & Marascu, 2015).
- Shine (Seiso): Removing the source of dirt and keep the parts clean. Quality can be achieved only by the most cleaned working conditions (Filip & Marascu, 2015).
- Standardize (Seikestu): Create a standard rule and maintain standard so that it reduces the search time and avoid mistakes (Filip & Marascu, 2015).

- Sustain (Shitsuke): All the activities are monitored, examined and improved continuously to maintain the results for a longer period (Filip & Marascu, 2015).

One important objective of 5S is to prepare the work environment and to store the visual information (Filip & Marascu, 2015).

The eight pillars of total productive maintenance (TPM) are shown in figure 4.

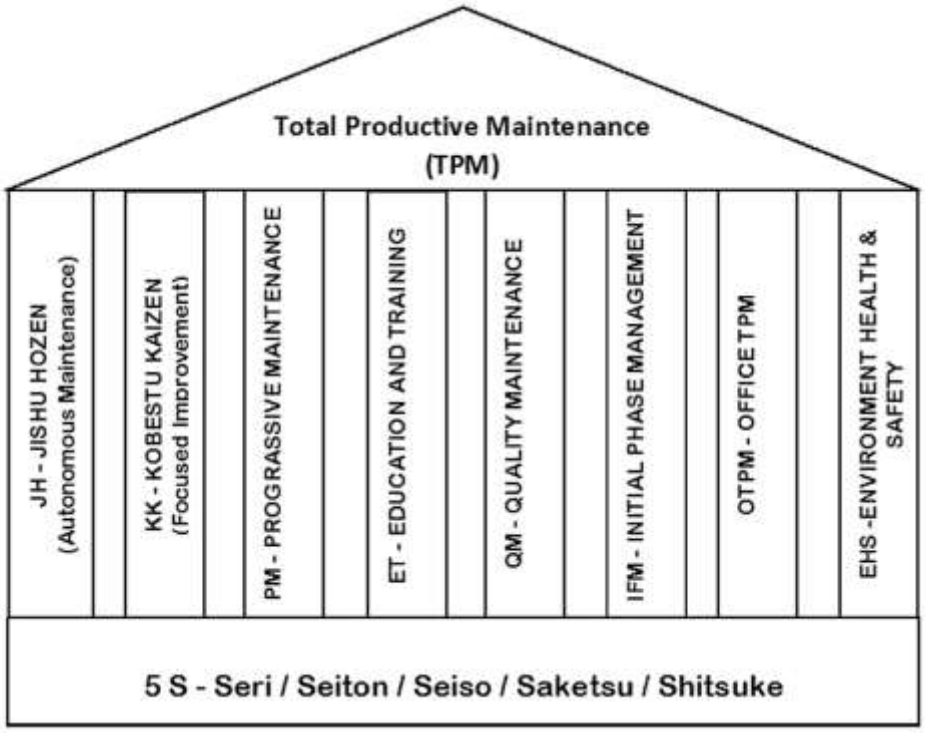


Figure 5 TPM PILLARS (Shinde & Ramjee , 2018)

2.6.1.1 Autonomous Maintenance:

In Autonomous Maintenance, the operator has ownership of the machine and maintenance is taken care of by the operator (Shinde & Ramjee , 2018).

2.6.1.2 Focused Improvement

Focused Improvement aims to identify and minimize waste. It eliminates the losses and helps to improve Overall Equipment effectiveness (Shinde & Ramjee , 2018).

2.6.1.3 Progressive Maintenance

It involves the preventative and predictive maintenance systems for equipment and tooling. OEE is increased because the 8 big losses are not generated (Shinde & Ramjee , 2018).

2.6.1.4 Education & Training

The education and training of the operator or employee increase morale by providing soft skill training and technical training (Shinde & Ramjee , 2018).

2.6.1.5 Quality Maintenance

Quality maintenance increases the quality products and also focus to achieve zero quality defects (Shinde & Ramjee , 2018).

2.6.1.6 Initial Phase Management

Initial Phase Management shorten the new product lead time, it is achieved using Vertical startup (Shinde & Ramjee , 2018).

2.6.1.7 Office TPM

Office TPM's objective is to ensure zero functional losses, create highly effective offices and provide sufficient service and support to the other departments in the organization (Shinde & Ramjee , 2018).

2.6.1.8 Environment Health & Safety

Environment Health & Safety creates a safe working environment for the operator. It also insures and sustains the zero accidents, creates a healthy workplace (Shinde & Ramjee , 2018).

2.7 Total Quality Management

The term quality can be defined in many aspects it's a significant element of production or services which make the customer satisfied. The overall efficient running of the machinery, visibility and autonomy, consultation and coordination with other departments is the key elements to consider in the quality department . According to (Dale, Boaden, & Lascelles, 1994) the evolution of quality management is categorized into four stages inspection, quality control, quality assurance and total quality management.

- **Inspection**
  A simple inspection-based system, one or more characteristics of a product, service or activity are examined, measured, tested, or assessed and compared with specified requirements to assess conformity with a specification or performance standard (Dale, Boaden, & Lascelles, 1994).
- **Quality control**
  product and performance specifications, a paperwork and procedures control system, raw material and intermediate-stage product-testing and reporting activities, logging of elementary process performance data, and feedback of process information to appropriate personnel and suppliers (Dale, Boaden, & Lascelles, 1994).
- **Quality assurance**
  Quality assurance is a prevention-based system which improves product and service quality and increases productivity by placing the emphasis on product, service and process design (Dale, Boaden, & Lascelles, 1994).
- **Total quality management**
  Total quality management requires that the principles of quality management should be applied in every branch and at every level in the organization with an emphasis on integration into business practices and a balance between technical, managerial and people issues (Dale, Boaden, & Lascelles, 1994).

Total quality management (TQM) is an integrative organizational-wide philosophy aimed towards continuously improving the quality of products/services and processes in order to meet or exceed customer expectations (Baird, Hu, & Reeve, 2011). The impact of TQM was measured and their results showed that the improvement was consistently stronger for firms with more advanced TQM systems (Moballeghi M., 2011). The key elements of the concept of TQM are:
1. Focus on consumers
2.Continually improving and increasing customer satisfaction
3.Continuous reduction of the real cost
4.A systematic approach
5.Horizontal integration of functions and classes
6.Participation of all employees
7.Inclusion of supply chain and customer chain (Topalović, 2015)

According to (Agus, 2011) also identified other four important elements of TQM practices namely:

1.Supplier Relation
2.Benchmarking
3.Quality
4.Measurement

2.8 Overall Equipment Effectiveness

Overall Equipment effectiveness is a major tool used to check the performance of the Total Productive Maintenance. The tool is used to measure a single machine and continuous machine effectiveness (Wudhikarn, 2016). OEE is a quantitative metric for measuring the performance of the production system. OEE is a dependent variable that is influenced by Productive Maintenance and Quality Management (Batumalay k & Santhapparaj, 2009). Overall Equipment Effectiveness is a function of equipment availability, process performance and a quality yield. These elements measure equipment and production losses (Chong & Kam Choi , 2016).

OEE= Availability * Performance* Quality

Equation 1 Overall Equipment Effectiveness

Availability = Operating Time/Loading Time
Operating Time = Loading time – Down time
Performance = Cycle time* Actual output/Operating Time
Quality= Total Production parts-defects products/ Total Production parts.
The OEE is measured using the consideration of all the major six losses. The six losses can be classified as follows.

- Equipment Failure.
- Setup and Adjustment Loss.
- Idling and minor stoppage.
- Reduced Speed.
- Defects in products.
- Reduced Yield (Batumalay k & Santhapparaj, 2009).

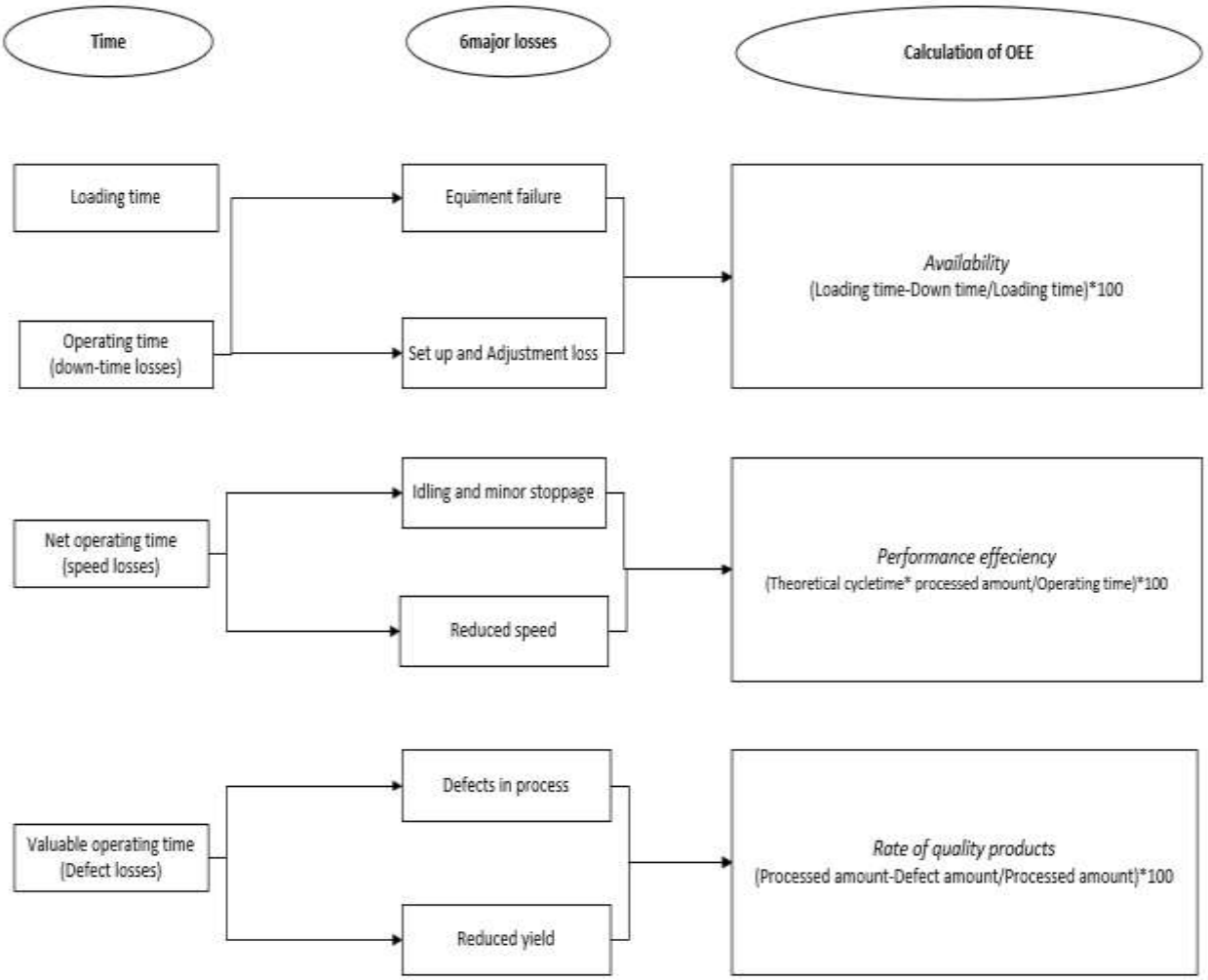


Figure 6 The OEE Formulation and the six losses (Batumalay k & Santhapparaj, 2009) .

2.9 Value Stream Mapping

Value Stream Mapping is used to identify all kinds of waste involved in the production process. VSM provides a visual platform to catch the time, resources involved for the individual activities that involved in the production system to produce the final product (Tyagi, Alok , Xianming , & Kai , 2015). The Implementation phase that occurred in the value stream mapping is shown in figure 5.

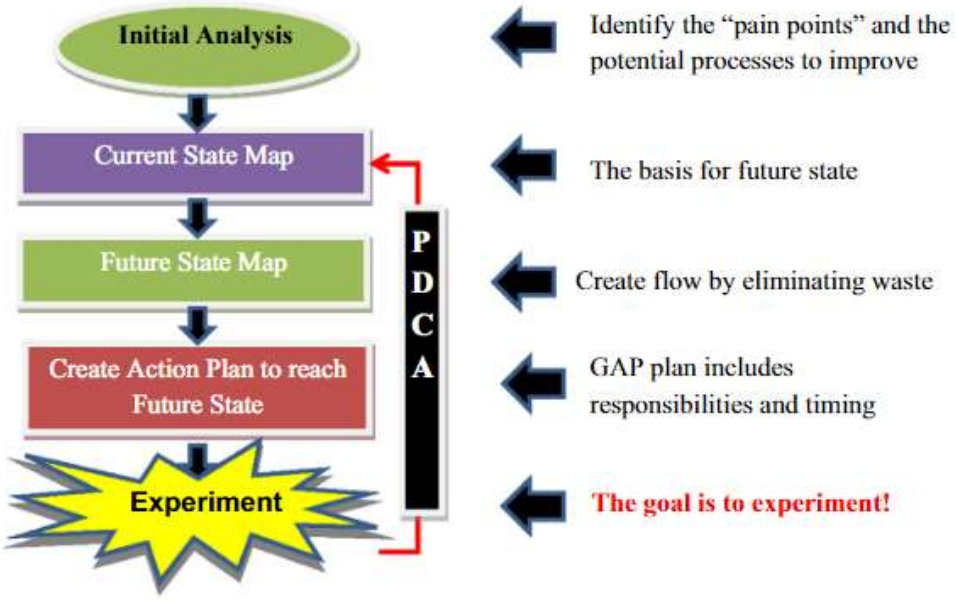


Figure 7 VSM Implementation Phases (Tyagi, Alok, Xianming, & Kai, 2015).

A value stream consists of all the resources like materials, information that is required to produce the product and the process flow carried out in the manufacturing system is visualized (Che10). A value stream map consists of two states namely the current state map and future state map. In the current state map, an ideal flow of information and materials is shown. A future state map represents the future state of the system that eliminated the waste that occurred in the existing production system (Chen, Li, & Shaddy, 2010). VSM provides the global vision of the activities that are carried out in the production system and it also enables to identify of the waste that occurred in the system (Lacerda, Ana , & Helena , 2016).
The lean metrics used in the VSM are

- Lead time
- Cycle time
- Takt Time

Lead Time:

The lead time is the time that includes all the process time, and the waiting time in between the process (Panneman, 2017).

Cycle Time:

It is the time involved in between two good quality products manufactured (Panneman, 2017).

Takt Time:

Take time is the rate between the customer requirement and the products manufactured in the production line (Panneman, 2017). Takt time can be calculated using the following formula

Takt Time = Available work time per shift/Customer demand rate per shift
(Panneman, 2017).

Value Stream Mapping tool is used to map a production process. In the map, it not only shows the material flow of the process it also indicates the information flow and production control (Braglia, Gionata , & Francesco , 2006). In the current state map, the icons used in the map are shown in figure 7.

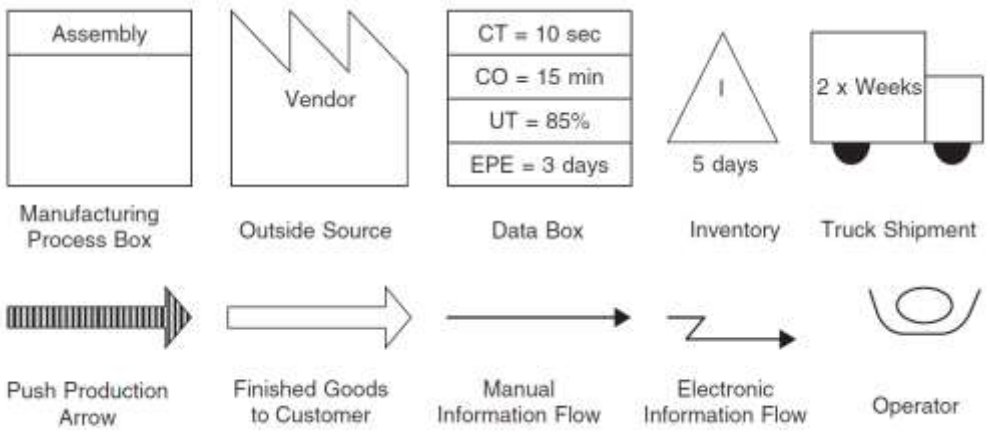


Figure 8 Current State Map Icons (Braglia, Gionata , & Francesco , 2006)

In the future state map, the icons used in the map are shown in figure 8. And the future state map can be obtained by answering the questions listed on table 1.

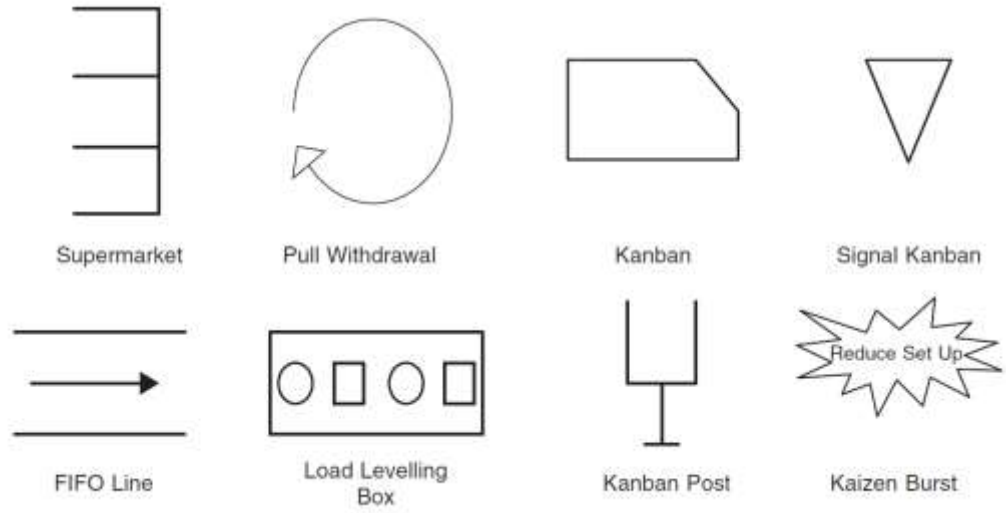


Figure 9 Future State Map Icons (Braglia, Gionata , & Francesco , 2006).

2.10 Activity-Based Costing:

The concept of activity-based costing is a methodology used to overcome the limitations of the traditional costing method. An activity-based costing method is a tool that brings the improvement in the quality of overhead cost allocation (Popesko, 2010). The basic concept of ABC is to allocate the cost involved in the various activities that can be measured by the cost drivers. ABC consists of various levels of activities (Popesko, 2010). Activity-Based costing seeks to identify the relationship to the assigned cost for the activities. Activity-Based Costing is a new method of calculating the cost involved in the individual process, products and customers. Activity-Based Costing is not the only tool used to calculate the individual cost, but also used as a cost reduction technique (Hudakova & Radoslav , 2015). The method is used to calculate scheduling for indirect costs involved, also schedule the causal relationship between activities and the individual performance measurement (Hudakova & Radoslav , 2015). There are four key concepts involved in the ABC systems.

- Activity Accounting
- Cost Drivers
- Direct Traceability
- Identification of Non-Value-added costs (Tsai, Hui-Chiao , Jau-Yang , Shu-Ping , & Yu-Shan, 2011).

The major difference between the traditional cost systems and Activity Based cost system is shown in table 3.

Table 1 Comparison between Traditional cost system and Activity-based cost (Ozyurek, 2014).

Typical systems	Activity-Based Accounting Systems
One or a few indirect costs for each department or whole plant	• Many indirect cost pools because of many activity areas. • Operating personnel play a key role in designating the areas
Indirect cost application bases are maybe cost drivers	• Indirect cost, application bases are more likely to be cost drivers
Indirect cost application bases are often financials as direct labor costs or direct material costs	• Indirect cost, application bases are often nonfinancial variables, such as number of parts in a product or hours of test time

Cost = Cost Pool/Cost Driver * no of products produced.

Equation 2 Cost Calculation

The Major purpose of the Activity Based Costing systems, seeks the answers for the following questions.

- What activities are being performed by the organizational activities?
- How much does it cost to perform organizational activities and business processes?
- Why does the organization need to perform activities and business processes?
- How much of each activity is required for the organization's products, services and customers? (Hamide & Yusuf , 2014)

2.11 Spaghetti

Spaghetti diagram is a mapping tool that is utilized in lean improvements. The results of the spaghetti diagram are to identify the inefficient movements of the worker or material inside the workstation area (SENDERSKÁ, Albert , & Štefan , 2017). Spaghetti diagram is to visualize the unnecessary flow of the materials or the workers inside the production systems. The spaghetti diagram is a representation as shown in figure 10.

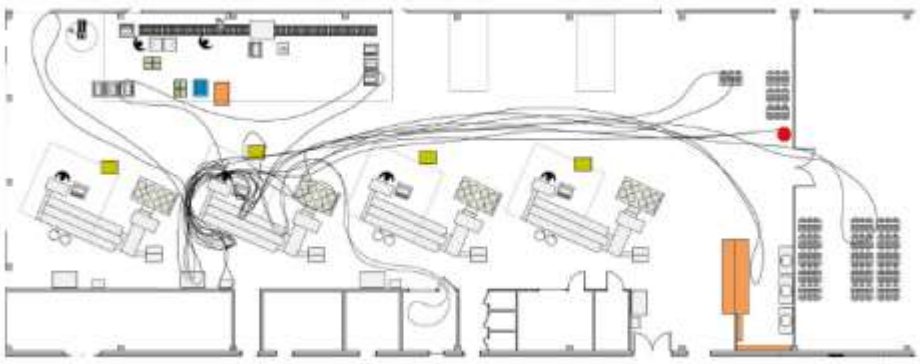


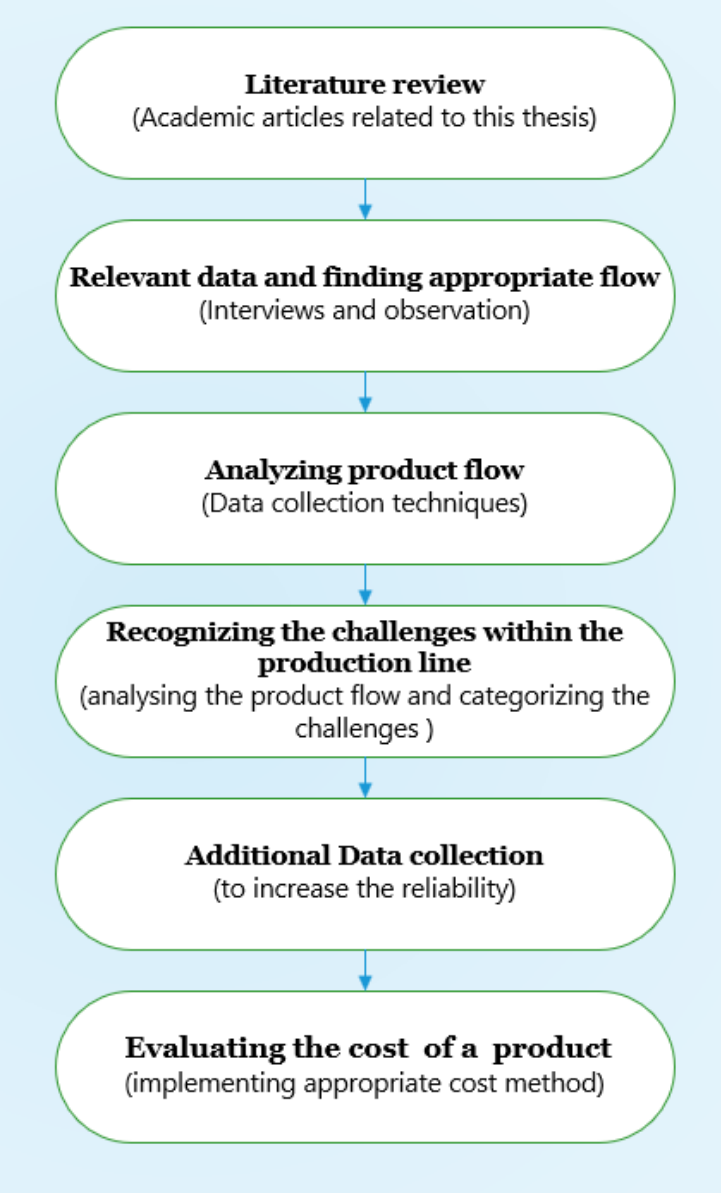
Figure 10 Spaghetti diagram (SENDERSKÁ, Albert , & Štefan , 2017).

3 Method and implementation

In this chapter, the first section is used for the structural approach that was used to answer the research questions explained. Followed by, insight into the case company is explained in detail before choosing the selected research method. The final section of the data collection techniques which are used for this thesis is presented.

3.1 Structural method relevant to research questions:

It is always necessary to have a systematic approach to collect relevant data with respect to the research questions There are Six main stages to describe the research question of the project. Structural method relevant to the research question:



3.1. 1, Literature review:

In this topic, the related literature and academic articles from several sources are used to fulfill the requirements and also able to create a conceptual framework to evaluate the research question. The search strategies involved during the literature review help to understand the non-value-added activities that prevail during the production process. Also, a relevant understanding of the cost involved in the various activities during the operation on the shop floor is done through the literature review. The brief knowledge about the problem, background and context are obtained for the researchers through the literature review.

3.1.2 Relevant data and finding appropriate flow:

Due to the limited amount of time, the focal company management gave suggestions to focus on a particular product in which they predict future demand. The management predicted the future demand after they have done forecasting before the beginning of the thesis. Relevant information at the focal company is collected with the help of exploratory interviews. The exploratory interviews are carried out in a semi structure method. The observation is also carried out on the shop floor by the researchers to understand the product flow. The interviews and observation help to identify the appropriate flow within the production line.

3.1.3, Analyzing product flow:

After examining the current flow and with the literature review, the researchers used the appropriate and relevant data collection techniques

-CSM and time study to calculate the non-values added activities(waste).

-spaghetti diagram to have analyzed the unnecessary movement of the operators.

3.1.4, Recognizing the challenges within the production line:

The challenges within the production line in the company were identified by using literature review and data collection techniques.

-Machine Maintenance (TPM)

-Quality defects (TQM)

-Unnecessary transportation (JIT &5s)

3.1.5, Additional Data collection:

The key workers in the production line are invited personally and discussed the value and non-value actions that occur in the production line to increase the reliability. Internal data have also been collected from the management in order to compare the cost that occurred for producing a product.

3.1. 6 Evaluating the cost of a product:

After inspecting the product flow, with help of relevant literature review and data received from the management the researcher used the Activity-based costing method to evaluate the actual cost that occurs on the shop floor during the production process.

3.2 Case company:

The focal company is one of the leading producers of sheet metal products in Europe. They produce different types of sheet metal products for their customers as per their demand. They have different types of operations like the punching process, sheet metal smoothening process (fladder), laser cutting process, bending process, and drilling process (Häger) to place the nuts and bolts. They layout prevailing to produce their products in the case company is cellular manufacturing

3.3 Research method

3.3.1 Case study:

A case study is an empirical inquiry that explores a current phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly noticeable (Yin, 1994) .According to the nature of the study, a case study is chosen as it gives depth data collection within the context of the study. To obtain high reliability in the research process, both quantitative and qualitative research methods have been combined (A.Marcoulides, 1998). Since, the purpose of this research is to optimize the cost using lean tools, reduce lead times and find value and non-value-added times the data collected from the case company was both qualitative and quantitative approach. Qualitative is used to find the non-value-added activities that prevail in the company and their reason for existence. From the quantitative approach using observations, collected data from the case company were related to the number of raw materials, size of the area for different storage methods and measurements of the inventory warehouse (Näslund, 2002). From the quantitative approach using interviews and secondary data, collected numerical data were related to the amount for a particular period (Näslund, 2002). Quantitative for calculating the present waste in terms of mathematically based method.

With help of selected method and the case study's design, the required amount of data has been collected from interviews, observations and documents (provided by the company) was collected, which resulted in a triangulation of empirical data.

3.3.2 Data Collection:

Data collection for the case study can rely on many sources of evidence. The major data collection is done from different sources like documentation, archival records, interviews, direct observation, participant-observation, and physical artifacts.

3.3.2.1 Interviews:

According to (Patton, 1987), the primary intention to carry out the interviews, because it is the most relevant technique to gather qualitative data which can be used to understand the investigating field. Another important aspect to consider when

designing an interview is to what degree the interview should be structured (Williamson, 2002). For this thesis, the semi-structured interviews are carried out in the case company. To have interviewed more like a discussion with managers and engineers in the company rather than to limit the data by having a structured interview (Williamson, 2002). The question with operators is more like unstructured as the questions were not prepared and asked on earlier experience or theoretical ideas.

For this thesis, two different were conducted to collect the data. the first one was an explanatory interview to have a broad aspect of the logistic management and to understand deeper knowledge of the material flow. Followed by explanatory where specific people are interviewed who work on the shop floor for the particular product flow.

3.3.2.2 Exploratory interviews

To obtain a broad view and to understand the overview of the logistic management of the focal company the exploratory interviews were carried out. By using funnel techniques, the interviews were conducted to have the broader aspect and funnel it down to specific with respect to the objective of suitable flow to study. For these key employees were identified and interviewed in their leisure time (team manager, quality engineer, supervisor). The respondents are subjected to feel free to express themselves to create a safer environment (Patel, 2011).

New questions were developed during the interview session and further questions are asked to clarify the doubts and the questions were prepared more like a semi-structured way. Before conducting the interview, the invitation is sent during the visit to the company or through email.

3.3.2.3 Explanatory interviews

To collect qualitative and quantitative data the explanatory interviews were conducted through the thesis from the key individuals in the focal company. The aim is to collect data to find the value and non-value-added activities that occurred in the production flow and to find an appropriate cost optimization.

Depending upon their designation the questions and the information obtained varied from the key individuals (team manager, quality engineer, supervisor, operators and truck drivers). So, the questions were semi-structured with open and closed questions.

3.3.2.4 Observations

To gain more knowledge and to have an insight into the current situation of the company observation is one of the key techniques to collect the data (Williamson, 2002). It is necessary to conduct the observation more systematically and it is essential to document the information (Patel, 2011).They also explained that it is suitable techniques that should be conducted in a natural environment when the phenomenon is subjected to be studied. During this technique's factors like the flow of material, operator activities, inventory areas and other aspects related to the research questions are observed and documented. According to (Williamson, 2002) there are different techniques for recording and documenting can be applied to the different observation styles:

-*Ad libitum*: the observer has limited knowledge regarding the phenomena.

-*Focal*: the observer to select a specific individual, group or event to be studied over a period of time.

-*Scan*: the observers with a quick scanning, or a snapshot.

-*Behavior*: the observers can focus on selecting a specific event or behavior of interest in the field.

For this thesis, all four types are used to collect the relevant data that is required to fulfill the research question. In the initial stage, ad libitum and focal data are used and followed by scan and behavior data are used to identify why, when this occurs for the specific individual.

3.3.2.5. Internal Documentation

The documentation of the material flow of a product, the time is taken to produce the products, waiting area, and VSM of the product have been previously calculated from the company when their demand was low. This documentation helped us to compare and analyze the data which were collected from us. The documentation gives us the detail of the characteristic of the material and helped us to know how the same material is used for other product. This helps us to get a rough picture of the value and non-value-added activity that exists in the company. The data also explains the characteristic of their machine and downtime to produce a product.

4 Findings and analysis

In this chapter, we going to discuss the current problem in the company and the analysis of product flow. The studied material flow findings are presented with the help of data obtained from interviews and observation. In the last part, the summary and the analysis of the material flow is explained.

4.1 Product Flow

There are many product flows within the company, after discussing with the production manager, suitable material product flow is chosen to optimize the cost of the product. All the action which is carried to produce the product is directly related to the cost. With the help of focused observations and data collection, the wastes are identified that prevails within the production line. The side panel for the computer cabinet which has future demand, and they have a goal to produce more products without investing additional cost. As we had a brief interview with the production manager, he mentioned that currently, they produce around 400 products for two weeks i.e. in a month they produce around 800 products. The product flow in different stations. They have six different halls, in each hall different types of the process take place to produce the product.

-Hall 1 (inventories)

-Hall2 (Punching process)

-Hall3(Punching and sheet metal smoothing process)

-Hall4(Laser cutting)

-Hall5(Outbound and inventories)

-Hall6 (bending and Håger press)

The side paned flows through each hall except the" Hall4", which is dedicated only for laser cutting. The raw materials are stored in the inventories which are placed in racks. These raw materials are stored in inventories before a week, and the sheet metal used to produce the side panel can be used for other products too. Once the order is placed, the raw materials are taken from Hall1 to hall2 where the punching process takes place for the product.

4.1.1 Hall1

The incoming raw materials are stored in Hall1 before it goes to an actual production line. Most of the raw materials arrive before a week the production start. Some of the raw materials are used to other products. The material used for producing a side panels also used for producing other products. So, the raw materials can stay in the inventories for more than a week. Once the raw material arrived the fork lift drivers arrange and sequence the material according to the priorities. Then the Raw materials are then stored in a rack on a wooden pallet. Some raw materials differ from others i.e. size, thickness and what kind of material the customer need for their product. Later they label the wooden pallets, so that it is easy for the forklift drivers to pick the right pallet at right time.

Figure 11 Raw Materails in Hall 1

4.1.2 Hall2

With respect to the production planning schedule punching process is carried out. The required amount of raw material is transferred from inventory area to punching area. They have five type of punching process machine which work fully automatic. Since the productivity of the side panel is less it always has the least priority in terms of production compare to other products which eventually influence the availability of machines. Each machine has its own characteristics and cost differs from machine to another. The operators have the schedule plan before actual production starts. The schedule plan describes the operator's daily task that should be carried out.

Figure 12 Punching Process in Hall 2

4.1.3 Hall3

In this area there are punching and sheet metal smoothing machines are available. After the punching process the product moves to smoothing machines to keep the edges smooth of the product. This process removes the scrap or unwanted particles in the material and gives a perfect surface finishing.

Figure 13 Fladder Machine in Hall 3

4.1.4 Hall6

The fork lift drivers pick the side panel and moves towards next process bending. There are different types of bending machines that are available in the shop floor. In the bending process, the product flow through the manual process and it can flow through any one of the bending machines in the hall6 as per the availability of the machine. There are also other machines in the hall6 known as drilling process where the nuts and bolts are fixed in the side panel as per the schedule plan.

Figure 14 Bending Process in Hall 6

Figure 15 Håger process in hall 6

4.1.5 Buffer stations

When the exploratory interview takes place, we found that side panel doesn't flow from one station to other instead it stays longer period in buffer station. The side panel has least priority now, as the demand is less. So, when the high demand products need to finished then the side panel needs to wait in buffer station. With help of observation techniques and exploratory interviews we found that product the stays more in bending process buffer station. When we discussed with management they said that the unfinished products can be stayed in for weeks which clearly indicates they aren't following push system. The waiting time for the side panel to finish is directly proportional to the demand and availability of the machine.

4.1.6 Hall5

The finished side panel are taken from the bending process area to the out-bond area (Hall5). Later side panel are packed and stored in big wooden pallets. They arranged

in the rack with respect to the delivery time. The label was marked to the side panel along with other products. We also witnessed that some of the raw materials are also stored in the out bound area. When we consult with response to the outbound area, he mentioned that these raw materials are the materials which are frequently used by the customer. So, they have two different racks for raw material and finished goods.

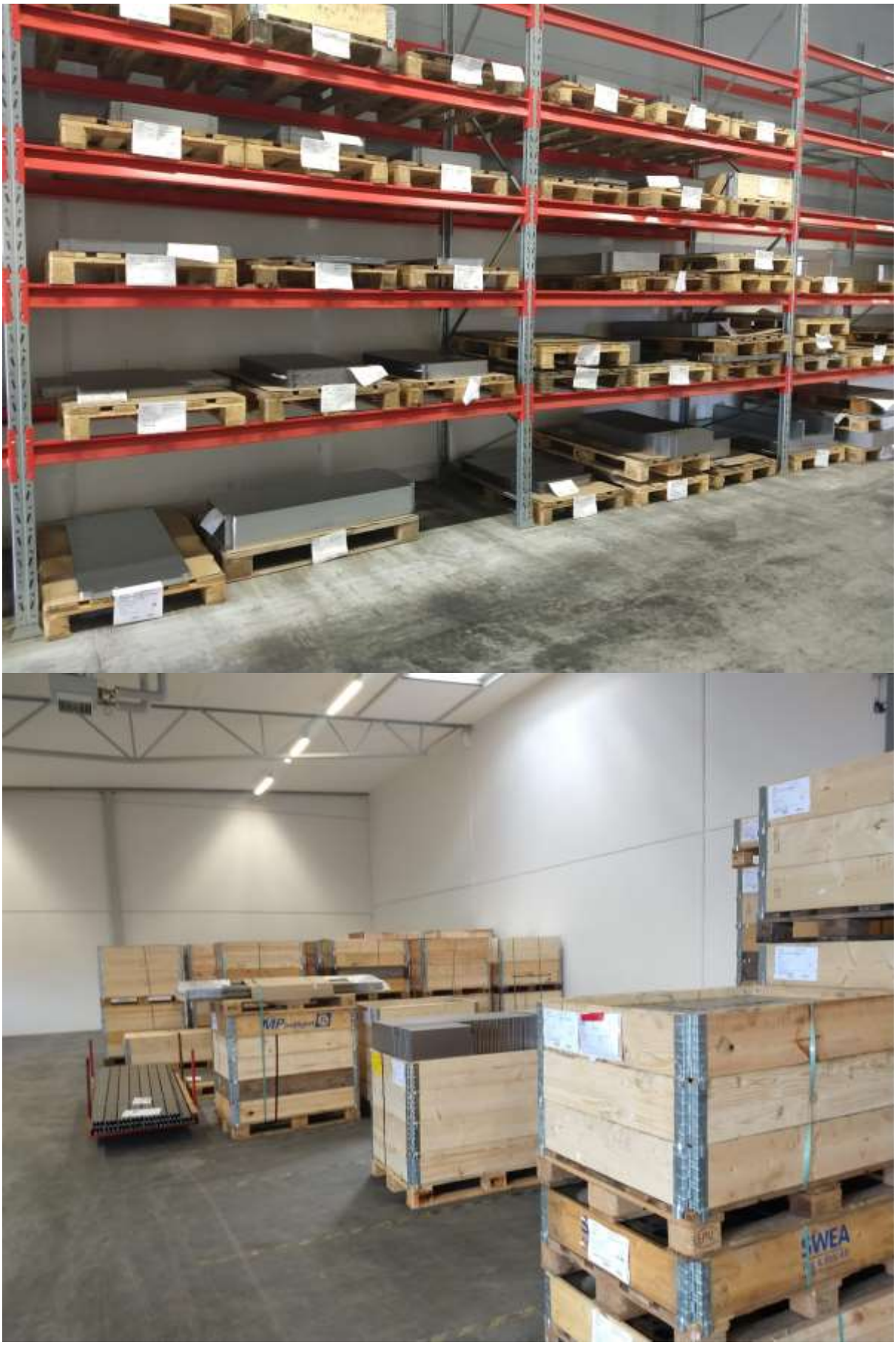


Figure 16 Outbound Area in Hall 5

4.2 Analysis of the side panel and its cost

On a broader aspect, one of the major drawbacks found in the findings is that the production on the shop floor an upon the top management. There is no consultation with middle or lower management, which result to unbalance inflow. Most of the raw materials are pushed from the inventories rather than the pull system. This creates a buffer and it has a huge negative effect on the production line. Due to a huge number of various products that flow in the production line creates uncertainties in terms of ordering the raw material. Also, the same type of materials is used for different kinds of products which made them uncertain in terms of the required raw materials. There are also different kind of automatic and manual machine that is used for producing the products. The same material that flows through one particular machine can change to another machine. This results in an unplanned buffer and temporary storage areas.

After looking at the spaghetti diagram for operators' movement and CSM, it is so evident that unnecessary movements and non-value-added activities prevail on the shop floor. After the bending process product needs to move back to the drilling process and then to the outbound area which resulted in unnecessary movements that affect the lead time. The forklift drivers to pick up the material from the punching process all the way to the manual bending process and then to the outbound area if the automatic machine isn't available.

It's so evident that the company's main agenda to achieve cost optimization it's important to reduce the waste that exists in the production line. It is also essential to differentiate which is non-value-added activities in the company to achieve cost optimization.

The waste identified inside the shop floor for the selected product is classified as follows:

4.2.1 Quality Defective Products

On the shop floor the defective product ratio for the side panel is comparatively high than other products particularly in the drilling process. This is due to the top management gave priority for other complex and high demand products. So, they failed to have a continuous quality check for the side panel. When we investigate more about side panel, we found that the company has tried to reduce the lead time of the process of side panel to have a cost optimization. So, the quality check is conducted after they produce few numbers of products. Once they identified the defects, the operators or supervisor contact quality engineers to identify the problem. So, in the meanwhile they start to produce other products that cause non value added activity (set up time). When we discussed to the operator, they mentioned that due to high variety of products flows in the station it's very hard for the operator to monitor a particular product. The quality manager is aware of the situation, but the production line needs to be running so that they can reach the numbers.

The researchers found that the resources like man, machines, tools are utilized to transform the raw material into the final product. But when the final product is defective then the time, resources used are waste so it directly influences on the overall cost and profits.

4.2.2 Machine Maintenance

In the shop floor we find the unnecessary stoppage of the machine, after the interviews and observation it has been found that the machine has been stopped working its functions due to lack of the maintenance. During peak hours, the operators fail to do continuous maintenance check for the products. In this case, it happens in automated punching process, where the operators have higher maintenance issues for the products and the quality departments has been conducted after the defect's products produced. We witness some tool wear issues, for the side panel and when we consult to the respective operators, they gave reasons that it is due to high production, they don't have time to autonomous maintenance and also, they need to concentrate to run the production line. The company also conduct maintenance once in a month for just an hour but it isn't sufficient when there is lot product flowing through the line. These problems have a huge impact on the product flow but the operators and other management aren't giving more priority as the number of productions for the side panel is low. Due to operator attitude they just fail to focus on the waste and didn't try to eradicate from the production line. The maintenance problem directly affects the cost. Moreover, the side panel is a type of product where the reworks isn't possible so the defects product goes to scrap which create waste and waste is directly proportional to the cost.

Due to maintenance issue, minor stoppage and buffer occurs which can't be controlled by the operators. The production engineer aware of the situation and tries to educate the operators and the guide the supervisor but as it mentioned before, during the high production flow it's very difficult to monitor and control.

4.2.3 Unnecessary Transportation

In the company the researchers found there is lot of unnecessary transportation in carried out. Both operator as well as WIP (Work in progress) are moved inside the shop floor. The fork lift drivers are subjected to drive the goods from one station to another as a part of the production flow. But the manual bending process is situated far from the out bound area which isn't efficient in terms of cost. The frequently used goods are placed near the outbound area, and the some of the raw materials are stored in the inbound area. The fork lift drivers need to drive all the way long to pick the raw materials to the specific station. During the observation it is noted that the operators need to pick a tool which is placed far from their work station. Then we visualized the work in progress unfinished products are driven in to the storage section due the storage problem inside the shop floor during the production process. The machine unavailability due to asynchronous transfer the time difference in-between the two-work station creates this situation. One of the main issues is the space constraints.

4.3Performance of the Production system

The management doesn't know the performance of the production system during the production process. The researchers used the OEE to measure the performance in the shop floor of the focal company

According (Wudhikarn, 2016) OEE can be calculated by the following equation

OEE= Availability * Performance* Quality..... equation (1)

For example, the ideal working condition in the focal company is 8 hours pers shift with short and meal breaks 60mins.The following procedure shows to calculate the percentage of availability, performance and quality.

Availability

For the case company , the machine availability is considered as available of the machine in proper working condition. For instance, if the downtime is 65 mins then planned production time 420 mins and operating time is 365 mins.

Availability= operating time/planned time

= (planned production time-down time)/ (total shift length -total breaks)

=84.5%

Performance

The performance of the production case is obtained by the following equation.

Cycle time * actual product produced /operating time.

For instance, ideal cycle time in the focal company is one minute to produce the one product and the actual product produced is 31pieces and the operating time 365 mins

Performance = 1*31/365

= 84.9%

Quality

Quality is the total number of good products produced in the total production. For instance, total number of products produced is 31 and the defective product produced in the shop floor due to non-value-added activities are 8. The focal company done the quality inspection at the final stage to reduce the lead time.

Quality= (total number of products -defective products)/total number of products

= (31-8)/31

=74.1%

From the given equation 1, the OEE can be calculated.

4.4 Cost of side panel using ABC:

The management doesn't know the current cost involved in the shop floor during the production process of the side panel. The researchers used the method of ABC in the focal company with help of literature review and observation.

According to (Gunasekaran & Daljit , 1999)Cost = Cost Pool/Cost Driver * no of products produced…. (Equation 2)

Cost pool

In the literature review the researchers found that cost pool nothing but a cost involved set up, material and depreciation which influence the direct cost. The set-up time of all processes to produce the side panel should be added to get the set up cost.

For instance, if the setup time of the punching process is 5 mins and the remaining all the process time is (20mins) then the setup time = 5mins+25mins=30mins.The focal company consider the hourly wages for the operators. For example, the hourly wages of an operator are 150sek and number of operators work is 5, then the cost involved on setup process is calculated as

set up cost -30*75*5= 11250sek.

The hourly wages are consider as 75sek in this case because the setup time is carried only for 30mins out of 60 mins. So, the operator salary is considered according to the individual activities he carried to produce the product in the shop floor.

The focal company purchase the raw materials from the supplier for all the product family. Since the same raw materials are used for different kind of products. The focal company needs to identify the number of product families that flows within the shop floor. For instance the number of product family is 5, and the total cost involved for purchasing the raw material is 6,000sek then for a single product material cost can be calculated

Material cost- 6,000/5=1200sek for a single product family

In order to calculate the depreciation cost, it is essential to know when the machines are bought and installed in the company. Then we need to calculate the depreciation rate for a year. But the researchers find difficult to calculate for each part or operation because the same machine is used for several products and parts. For example the depreciation cost can be calculated

Depreciation cost=Machine purchased cost- (depreciation rate*number of years)

=50,000-(3000*3)

=41,000sek

Cost drivers

The cost drivers nothing but a cost involved in maintenance, material handling cost, labor, inspection cost which influence the indirect cost. Similar to the setup cost calculation of maintenance, material handling of raw material WIP and finished goods (includes within the shop floor), inspection cost is calculated. Labor cost is calculated based on the number of employees working in the focal company . The number of hours they worked for a particular time period should be considered. Labor cost include the paid vacation cost, overtime cost and exclude employment union cost, sick leave cost, pension cost.

For example, a labor worked for 140 hours in the focal company for a month, hourly wages are 150sek and total number of employees is 200, then the labor cost is calculated

Labor cost-140*150*200=42,00000sek.

Electrical cost can be calculated based on total electrical consumption rate (shop floor and office) of the focal company. Electrical unit price should also consider to calculate the electrical cost, the electrical unit price also varies depending upon the focal company location.

For instance, total electrical consumption rate for a month is “1700kwh”, electrical unit price= 800sek/month electrical cost = electrical consumption rate*electrical unit price

Electrical cost-1700*800 =1,36,0000sek

Number of products produced

The number of products is calculated either by forecasting the customer demand or goods delivered from the focal company for a certain period of time.

With help of equation 2 ABC of production system in the focal company can be calculated.

5 Discussion and conclusions

5.1 Discussion of method

The purpose of the research question is to answer them researches choose the case study which is the appropriate method to satisfy the needs of this research. The researchers choose case study because of its reliability and validity. The researchers choose case study to Investigate the problem and their effects on other performance like cost, quality. The researchers conducted many types of data collection techniques like interviews on internal documentation, observations. The triangulation method which is used in this thesis to study the phenomena increases the validity and reliability. Simultaneously researchers did the literature study so that the similar kind of problems and their implication on the different case is analyzed.

The data collection techniques help the researchers to understand the current situation of the systems. It helped to map the flow of materials in the shop floor and all the activities in the shop floor from the ordering of the raw material to the delivery of the final product. A semi structured Interviews is carried out by the researchers so that the participants have their own freedom to answer the questions. The observation technique helped the researchers to identify the flow and answer the research on practical implications for the individual case. This result identifies the lead time of the selected product which consists of both values added and non-valued time. The internal documentation technique enriched this case problems related to the defects or quality related issues for a certain amount of time. This helped the researchers to understand the quality related issues and their direct relationship with the cost involved in the activity.

The finding and analysis using a literature study help to increase the validity and reliability of the research. By the validity and reliability, the results found in the case company can be generalized to some extent. The major delimitation of this research that the research is carried out on a single case company. To increase the validity and reliability the research carried out on the multiple case companies. If more time is provided then the researchers could do the same research with more range of product families in the case company so that it also helps the company to understand their own strengths and weakness of the production flow and also leads the company to improve their production techniques without compromising with quality and deliverability of the product. The answer to the third research question helped the research to fulfill the objective of the thesis as well as it also helps the research results to generalize to similar situations.

5.2 Discussion of findings

RQ1. What are the non-value added activities that existed in the process to produce a particular product?

Before implementing the change of process or giving suggestion the focal company needs to identify the prevailing waste on the shop floor. The value stream mapping is the tool that helps to identify the non-value-added activities. The researchers found that the set-up time as a non-added time but it can't be neglected as it is essential to start the process. The focal company can able to identify the cycle time, downtime and buffer using VSM. The spaghetti diagram is used to monitor the movement of the operator. The unnecessary movement of the operator has been identified due to the lack of tool which isn't placed at the right place, unavailability of the machine which has been observed by the researchers and calculated in CSM. The lack of maintenance issues has been identified due to multiple product flow. The unnecessary transportation of the material from the work station to the buffer station is due to the unavailability of the machine which solely based on the lack of maintenance. The unnecessary movement of the forklift drivers is due to the space constraints and lack

of information flow. By identifying the following waste required lean tool can be suggested for the focal company.

RQ2. How can lead time be reduced for a particular product?

The lead time can reduce with the help of the minimization or eliminating the non-value-added activity. But it's essential to find the root cause problem before eliminating the current problem. To eradicate the root cause various lean tools are suggested to the production supervisor on the shop floor.

5S &JIT
A detailed description of the work procedure should be placed and the details of the required tools should be placed near to the workplace. So, the operator can check all the required tools and raw materials are placed before the actual production. By doing this the unnecessary transportation can be minimized by the operators. Since the many products flow through the shop floor, it is good to have a pre-planned schedule before a week, so the WIP can be reduced or eliminated. Also, once the pre-planned schedule is made then the operator can arrange the tools for the required products to be produced that flows on the shop floor. Communication between each station and education for the operators should be given to make them work efficiently on the shop floor.

Once the pre-planned schedule is given the raw material to be used in the production process can be calculated in numbers rather than approximate figures. The same kind of raw materials is used for different kinds of products with help of pre-planned schedule the forklift drivers know how much amount of raw materials can be transported to the respective process. This eventually reduces the unnecessary transportation of the forklift drivers that prevails in the shop floor and the inventories. Inventory is an important factor that directly affects the other aspects of the manufacturing system like occupying the floor space, it can affect the lead time and efficiency. Unnecessary transportation is also due to the space constraints and complex layout which the management is planning to build a new shop floor in the near future.

TPM
One of the problems which have been observed on the shop floor is autonomous maintenance. The operator couldn't able to do the maintenance check especially in the automated punching process due to the flow of different characteristic products that prevailed in the focal company. Due to the more demand for other products, the maintenance check becomes impossible on the shop floor. The frequent maintenance check should be conducted with the help of a checklist where the operators are instructed to check and the list should be verified by the supervisor on the shop floor. The pre-planned schedule also helps the operator to predict the flow of products, which eventually helps them to plan for their maintenance check. Operators should have some basic knowledge of the machine so during the minor stoppage they don't have to wait for the experts to solve the problem. The pre-planned schedule can also give the solution for machine unavailability.

TQM
Quality issues in the focal company can be reduced if they check before the actual production. The sample production should be done before the actual production starts and the quality check should be conducted in different processes. The focal company does their quality check at the last stage of the process to minimize the lead time. By doing the quality check at the last stages there is an increased chance of quality defects product. The ratio of quality defects products is high in the drilling process which has been identified by the researchers. The reason behind for quality defects is because of

tool wear as the proper tool is not placed near the work station or the operator didn't check the tool after a certain product been produced. One of the reasons is also the required tool isn't near the work station which results in producing quality defect products.

OEE

The performance of the production system is calculated using OEE. The focal company needs to consider about the downtime. The downtime can be occurred due to the unavailability of operators, especially in manual process. So, the company should decide the product is flowing through the manual process or automated process. Once the quality issues are reduced or eliminated with help of above lean tools then while calculating the OEE the

Q3. How can cost-effectiveness can be obtained by implementing lean manufacturing to produce the particular product family?

The cost effectiveness can be obtained by selecting the proper cost measurement tool to measure the cost after implementing the lean tools. The activity-based costing is selected, the name itself implies that the cost is purely based on the activities involved in the process. The focal company needs to identify the activities that need to be converted in terms of cost. With respect to the activities the cost pool or cost drivers can be calculated. So, the improved activities achieved due to implementation of the various lean tool helps to the reduction of waste also increase the operational performance. The focal company needs to have an extra attention to calculate deprecation cost because the rate of wear to machines are really hard to predict. Based on the wear worn out from the current year to the previous helps to calculate the deprecation cost which is bit hard as different kind of products flow in the same machine. In addition, the same raw materials are used to produce different kind of products. So, it is essential to estimate how many raw materials are used for the particular product. To calculate the external factor like suppliers and transportation then lean accounting is the best tool. Combining the ABC and lean accounting precise cost optimization can be done in the focal company.

6 Conclusions

The cost plays the major role in the production systems. Since the global market is rapidly growing everyone trying their best to optimize the cost. In this case a case study is carried out in one Swedish company with help of lean tools the waste is identified and reduced to improve the overall performance of the system, then the cost involved in the production activities is optimized. The profit of the company can be used to meet their future high demand without investing additional cost.

In the future research the cost can be optimized in overall system rather than production activities with the help of lean accounting tool and the study can be carried out for multiple products and companies rather than single product and single company.

7 References

(Mark)Yang, M. G., PaulHong, & B.Mod, S. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics*, pg 251-261.

A.Marcoulides, G. (1998). *Modern methods for business research*. . Psychology Press.

Adesta, H., & D. Agusman. (2018). Evaluating 8 pillars of Total Productive Maintenance (TPM) implementation and their contribution to manufacturing performance. *IOP Conference Series: Materials Science and Engineering*, (pp. 13-18).

Agus, A. (2011). Enhancing production performance and customer performance through total quality management (TQM): strategies for competitive advantage. *Procedia-Social and Behavioral Sciences*, 24, 1650-1662.

Agustiady, Tina , K., & Elizabeth , A. (2018). Total Productive Maintenance. *Total Quality Management & Business Excellence* , 1-8.

Anvari, A., Norzima , Z., & Omid , A. (2014). Application of a modified VIKOR method for decision-making problems in lean tool selection. *The international journal of advanced manufacturing technology*, 829-841.

Batumalay k, & Santhapparaj, A. (2009). Overall equipment effectiveness (OEE) through total productive maintenance (TPM) practices—a study across the Malaysian industries. *In 2009 International Conference for Technical Postgraduates*, 1-5.

Braglia, M., Gionata , C., & Francesco , Z. (2006). A new value stream mapping approach for complex production systems. *International journal of production research* , 3929-3952.

Chan , F., Lau , H., Ip , R., Chan , H., & Kong S. (2005). Implementation of total productive maintenance: A case study. International journal of production economics. *International journal of production economics*, 71-94.

Chen, J. C., Li, Y., & Shaddy, B. D. (2010). From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study. *International Journal of Production Reasarch*, pg 1069-1086.

Chong, K., & Kam Choi , N. (2016). Relationship between overall equipment effectiveness, throughput and production part cost in semiconductor manufacturing industry. *IEEE International Conference on Industrial Engineering and Engineering Management*, 75-79.

Chowdhury, A. H., Shahriar, S., Hossen, T., & Mahmud, P. (2016). Reduction of Process Lead Time Using Lean Tool - Value Stream Mappin(VSM). *Applied Mechanics and Materials*, pg 74-80.

Christopher, M., & John , G. (2005). Supply chain cost management and value-based pricing. *Industrial marketing management*, 115-121.

Dale, B., Boaden, R., & Lascelles, D. (1994). 'Total Quality Management - An Overview',. *Managing quality*, 2,3-40.

de Arbulo-López, P., & Jordi , F.-S. (2010). An accounting system to support process improvements: Transition to lean accounting. *Journal of Industrial Engineering and Management* , 576-602.

Fernando Bernstein, A. G. (2009). Dynamic Cost Reduction Through Process Improvement in Assembly Networks. *Management Science*, 552-567.

Filip , F., & Marascu, K. (2015). The 5S lean method as a tool of industrial management performances. *IOP Conference Series: Materials Science and Engineering*, (pp. 1-6).

Gao, X. (October 2018). Corporate Cash Hoarding: The Role of Just-in-Time Adoption. *Management Science*, Vol. 64, No. 10,, pp. 4858–4876.

García-Bernal, J., & García-Casarejos, N. (2014). Economic analysis of TQM adoption in the construction sector. *Total Quality Management & Business Excellence*, pg 209-221.

Gavriluţă, A. (2019). Study on improvement of a manufacturing system using Lean Manufacturing. *Quality-Access to Success*, 365-370.

Gibbons, P. M., Kennedy, C., Burgess, S. C., & Godfrey, P. (2012). The development of a lean resource mapping framework: introducing an 8th waste. *International Journal of Lean Six Sigma*, Vol. 3 No. 1, 4-27.

Guimarães, L. d., Medeiros, H. S., Santana, A. F., & Pereira, M. S. (2015). Cost reduction in the production process using the ABC and Lean tools: Case Study in the refrigeration components industry. *GEPROS: Gestão da Produção, Operações e Sistemas*, 157-176.

Gunasekaran, A., & Daljit , S. (1999). Design of activity-based costing in a small company: A case study. *"Design of activity-based costing in a small company: A case study." Computers & Industrial Engineering* , 413-416.

Hamide , O., & Yusuf , D. (2014). TIME-DRIVEN ACTIVITY BASED COSTING. *International Journal of Business and Management Studies*, 97-117.

Hill, K. (2018, March 10). *Lean Manufacturing: 'The Seven Deadly Wastes': Find Greater Efficiency at Every Step of the Process*. Retrieved from plantengineering: www.plantengineering.com

Hong, P., & Leffakis, Z. M. (2017). Managing demand variability and operational effectiveness: case of lean improvement programmes and MRP planning integration. *The Management of Operations* , pg 1066-1080.

Hudakova, S., & Radoslav , B. (2015). Cost management using activity-based costing model. *Актуальні проблеми економіки* , 373-386.

Huq, F., & William E, P. (1996). Impact of short-term variations in demand on opportunity costs in a just-in-time kanban system. *demand on opportunity costs in a just-in-time kanban system." Production and Inventory Management Journal* , 8-13.

Ingaldi, M., & Marta , J.-K. (2014). Lean tool used in the automotive industry. *Production Engineering Archives*, 7-10.

Jayaram, J., Ajay , D., & Mariana , N. (2010). Looking beyond the obvious: Unraveling the Toyota production system. *International Journal of Production Economics* , 280-291.

Kant, R., L. N, P., & Vijay , P. (2014). Framework for strategic implementation of cellular manufacturing in lean production environment. *Journal of Manufacturing Technology Research* , 177-191.

Krafcik, J. (1998). Triumph of the lean production system. *MIT Sloan Management Review* , 41.

Lacerda, A., Ana , R., & Helena , M. (2016). Applying Value Stream Mapping to eliminate waste: a case study of an original equipment manufacturer for the automotive industry. *International Journal of Production Research* , 1708-1720.

Malta, J., & F.Cunha, P. (2011). A new approach for cost modelling and performance evaluation within operations planning. *CIRP Journal of Manufacturing Science and Technology*, pp 234-242.

Maskell, B. H., & Kennedy, F. A. (2007). Why Do We Need Lean Accounting andHow Does It Work? *The Journal of Corporate Accounting & Finance,*, pp 59-73.

Matthew Lindsey, R. P. (2009). Prediction intervals for future demand of existing products with anobserved demand of zero. *Int. J. Production Economics*, 75–89.

Mello, M. F., & Santos, A. B. (2016). THE IMPORTANCE OF COST MANAGEMENT IN A MANUFACTURING COMPANY OF HYDROELECTRIC PLANTS - A CASE STUDY. *Brazilian Journal of Operations & Production Management*, pg 94-99.

Metternich, J., Sven , B., & Stefan , S. (2013). Efficiency and economic evaluation of cellular manufacturing to enable lean machining. *Procedia CIRP*, 592-597.

Moballeghi M., a. M. (2011). Linking TQM and financial performance. *In 3rd International Conference on Information and Financial Engineering*, Vol. 12, pp. 417-422.

Näslund, D. (2002). Logistics needs qualitative research–especially action research. *International Journal of Physical Distribution & Logistics Management*, 32(5), 321-338.

Ng, K. C., C.P.Lim, Chong, K., & Goh, G. (2016). Elimination of Waste through Value Add/Non value Add Process Analysis to Improve Cost Productivity in Manufacturing - A Case Study . *Industrial Engineering and Engineering Management (IEEM)*, Pg 75-79.

Ng, K., C.P.Lim, Chon, K., & G.G.G.Goh. (2013). Elimination of Waste through Value Add/Non value Add Process Analysis to Improve Cost Productivity in Manufacturing - A Case Study. *IEEE International Conference on Industrial Engineering and Engineering* , pg 410-414.

Ofileanu, D., & Dan , I. (2014). Lean Accounting - An Ingenious Solution for Cost Optimization. *International Journal of Academic Research in Business and Social Sciences*, 342-352.

Ozyurek, H. a. (2014). Time-Driven Activity Based Costing. . *International Journal of Business and Management Studies*, 6(1), 97-117.

Pakdil, F., & Karen, M. (2014). Criteria for a lean organisation: development of a lean assessment tool. *International Journal of Production Research* , 4587-4607.

Panneman, T. (2017). *Lean Transformations - when and how to climb the four steps of Lean maturity*. Maarssen.

Patel, R. &. (2011). *Forskningsmetodikens grunder : att planera, genomföra och rapportera en undersökning*. Lund: Studentlitteratur .

Patton, M. Q. (1987). *How to use qualitative methods in evaluation (*. (No. 4). Sage.

Popesko, B. (2010). Activity-based costing application methodology for manufacturing industries. *E & M Ekonomie A Management*, 103-114.

Ruiz-de-Arbulo-Lopez, P., Fortuny-Santos, J., & Cuatrecasas-Arbós, L. (2013). Lean manufacturing: costing the value stream. *Industrial Management & Data Systems*, 647-668.

Samuel, D., Found, P., & Williams, S. J. (2015). How did the publication of the book The Machine That Changed The World change management thinking? Exploring 25 years of lean literature. *INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT*, pg 1386-1407.

SENDERSKÁ, K., Albert , M., & Štefan , V. (2017). SPAGHETTI DIAGRAM APPLICATION FOR WORKERS'MOVEMENT ANALYSIS. *UPB Scientific Bulletin, Series D: Mechanical Engineering* , 139-150.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, 129-149.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, pg 785-805.

Shinde, D., & Ramjee , P. (2018). Application of AHP for ranking of total productive maintenance pillars. *Wireless Personal Communications* , 449-462.

Thun, J.-H., Martin , D., & André , G. (2010). Empowering Kanban through TPS-principles–an empirical analysis of the Toyota Production System. *International Journal of Production Research* , 7089-7106.

Topalović, S. (2015). The implementation of total quality management in order to improve production performance and enhancing the level of customer satisfaction. *Procedia Technology*, 19, 1016-1022.

Tsai, W.-H., Hui-Chiao , C., Jau-Yang , L., Shu-Ping , C., & Yu-Shan, S. (2011). Using activity-based costing to evaluate capital investments for green manufacturing systems. *International Journal of Production Research* , 7275-7292.

Tyagi, S., Alok , C., Xianming , C., & Kai , Y. (2015). Value stream mapping to reduce the lead-time of a product development process. *International Journal of Production Economics* , 202-212.

Uhrin, Á., Sebastian , B.-C., & José , M.-F. (2017). Lean production, workforce development and operational performance. *Management Decision* , 103-118.

Walliman, N. (2011). *Research theory, Research methods: the basics*. 2nd ed. New York: Routledge Taylor & Francis Group.

Williamson, K. (2002). *Research methods for students, academics and professionals: Information management and systems*. Elsevier.

Wudhikarn, R. (2016). Implementation of the overall equipment cost loss (OECL) methodology for comparison with overall equipment effectiveness (OEE). *Journal of Quality in Maintenance Engineering* , 81-93.

Yin, R. K. (1994). Discovering the future of the case study. *Method in evaluation research. Evaluation practice*, 15(3), 283-290.

Yu, G. J., Park, M., & Hong, K. H. (2017). A strategy perspective on total quality management. *Total Quality Management & Business Excellence*, pg1-14.

Zaharia, V., & Bordeianu, D. (2018). COST STRATEGIES IN MANUFACTURING COMPANIES. *Proceedings in Manufacturing Systems;* , pg157-164.

8 Appendices

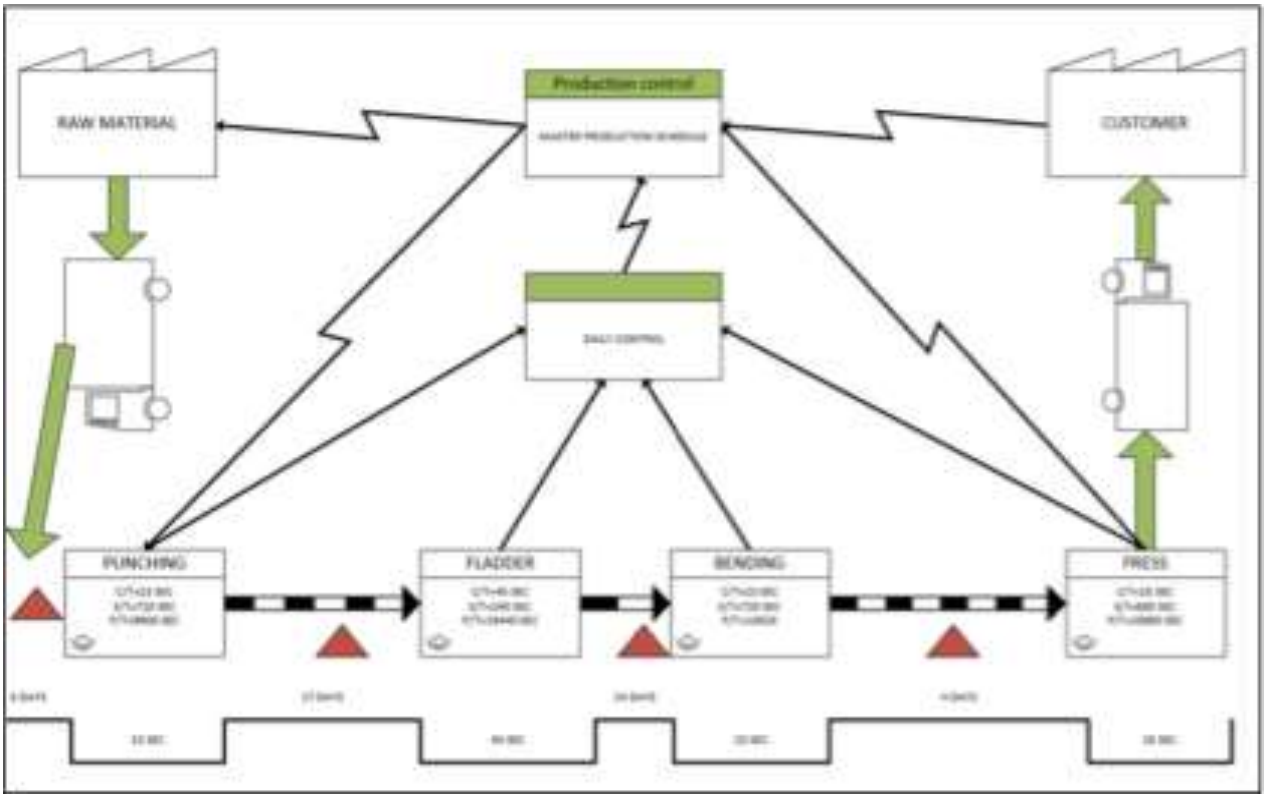
8.1 Interview Questions:

1. Could you explain yourself and represent your role and responsibilities in Gnosjö Laserstans AB?
2. How the production planning is carried out?
3. How long the raw material order is placed?
4. Could you explain the logistic flow of the product inside the shop floor?
5. What is production rate of product per month?
6. What is the reason behind minor stoppage in the production line?
7. Why the quality rejection rate is high?
8. What process is carried out for the defective products or scrap?
9. How the internal communication between the employee and top management carried out?
10. What are the external factors that affects the production in the shop floor?
11. How the KPI of production system is rated?
12. What are the parallel projects that takes inside the company?
13. How is the customer feedback of the products and services?

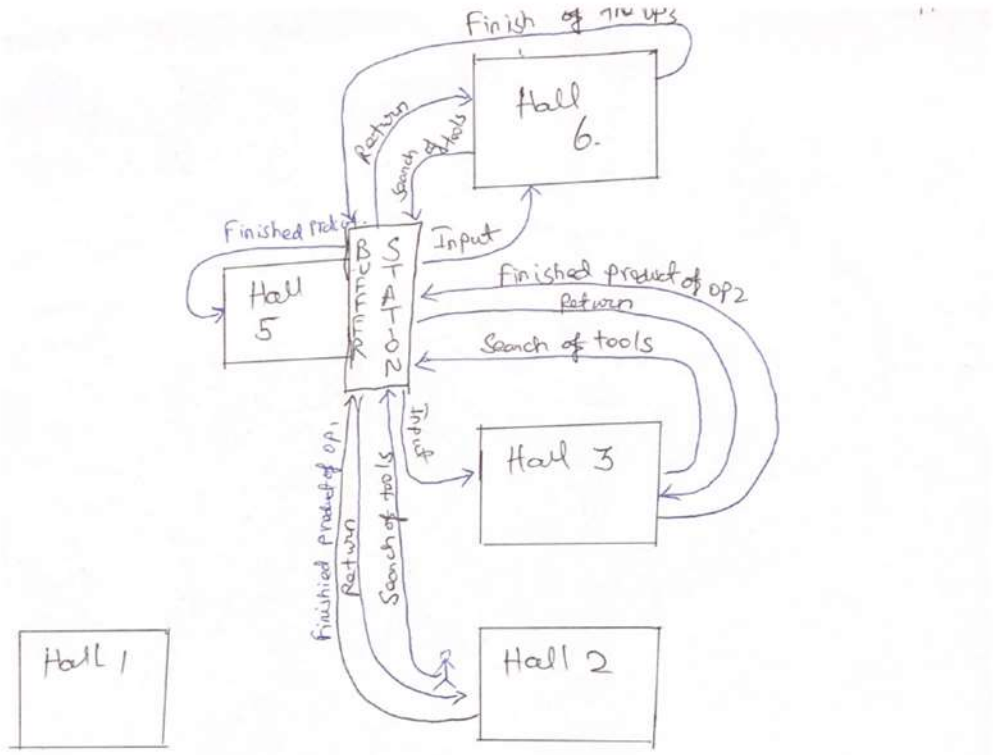
8.2 ABBERIVATIONS

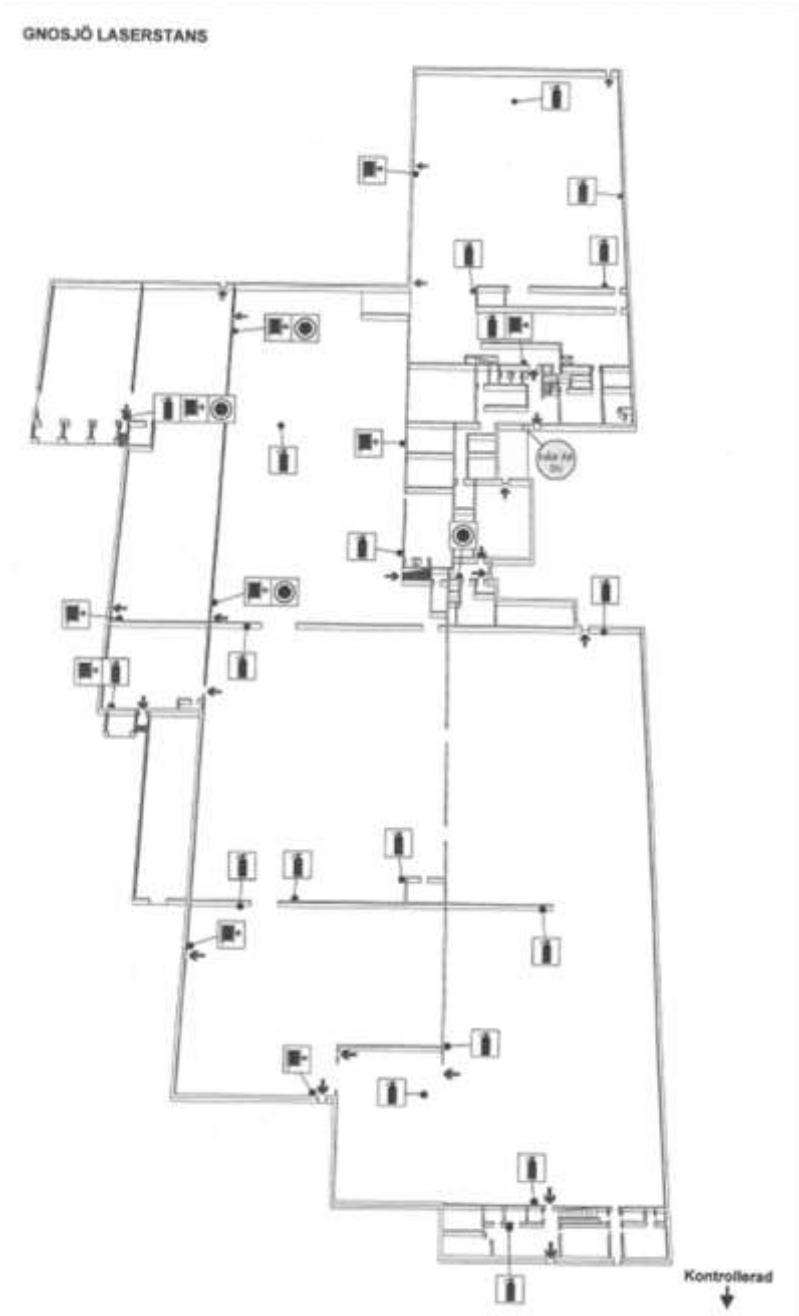
TPS : Toyota Production Systems.
JIT: Just In Time
VSM: Value Stream Map
CSM: Current State Map
ABC: Activity Based Costing.
TQM-Total quality Management
TPM-Total productive Maintenance

8.3 Current State MAP



8.4 Spaghetti Diagram (Movement of the operator)



* Hall 1- Inventories
* Hall 2- Punching
* Hall 3 - Punching & Metal Smoothing process.
* Hall 5 - Outbound & Inventories.
* Hall 6 - Bending & Hägar process.

8.4 Shoop Floor Layout.