

Implementation of Value Stream mapping in a job shop for High-Mix Low - Volume Environment

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ABSTRACT

In the present age of competitive manufacturing, every manufacturing industry wants to manufacture lean. One of the ways to achieve it is by eliminating inefficiencies in the operations. Value stream mapping is one of the vastly used tools to map value adding and non-value adding operations. However Value stream mapping cannot be used successfully on job shop in High mix-low volume production process because of variation in the cycle time. In this research, literature review on HMLV industries and its differences comparing it to mass production industries is shown. Value stream mapping as a tool and its applicable principles for future state mapping is given. By visual monitoring, current state map of the PSB shovel manufacturing was generated. Discussion with the production manager was carried out to map the future state based on the VSM principles.

The current state mapping of the PSB shovel manufacturing showed the duration of every operation performed. While mapping the current value stream shortest cycle time was recorded. Every operation involved was analysed and bar graph was generated. Comparison between time operated, expected operation time, time stamp and lead time was made. Based on the following analysis and VSM principles Future state map was generated.

The analysis shows the importance of monitoring in the job shop can lead to better future state of the production. Based on the results, it was clear that VSM tool could be used for monitoring and analysing the job shop in HMLV environment.

Keywords: - Value Stream Mapping, High mix Low volume, Lean Manufacturing.

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ACRONYMS

- CODP - Customer Order Decoupling Point
- HMLV – High Mix, Low Volume
- VSM – Value Stream Mapping
- ETO – Engineering-to-order
- FIFO – First In, First out
- PSS – Ploughshare Shovel
- PSB – Ploughshare Becker
- PS – Ploughshare
- PS-ERZ – Ploughshare Ersatz
- MIG – Metal Inserted Gas
- TPS – Toyota production system
- CSM – Current state map
- FSM – Future State map
- HVLM - High Volume & Low Mix

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INTRODUCTION

In the present manufacturing era, productivity, efficiency and effectiveness matters for any manufacturing industry. These manufacturing industries are keen towards increasing their productivity and profits. Some of the famous industries like Toyota increased their productivity by manufacturing lean. According to Toyota, to increase productivity the production should be lean. Being lean can be a time consuming and never ending process. Producing lean generally means, “to avoid non-value adding operations”, which are unpaid for and unnecessary.

Toyota’s lean way of mass production generated waves in the automobile manufacturing industries. It was the way they produced, with minimal waste and never-ending improvements. Toyota’s sensei implemented many ways to reduce the non-value adding operations. These ways are today known as the lean manufacturing tools. Many of the lean management tools used by Toyota are applicable for industries with non-variant products and mass production. These industries decide the demand themselves depending on the past sales. Due to this customer has no freedom to customise the products being sold.

Whereas the High-mix, low volume (HMLV) industries customer can customise the product based on their requirements and needs. As the variations in the production process increases manufacturing process are harder to standardize. The routings in the production floor gets complicated and it might congest the flow of the production. This will affect the cycle times of the operations in the process, consequently cycle times are hard to measure and monitor. As HMLV industries deal with huge variety of products the level of automation is minimal. This forces job shop manufacturing of the product variations. However scope of non-value adding operations is huge because of less automation. This allows any lean manager to make the process lean and improve it. To improve the process and reduce the non-value adding operations Value Stream mapping (VSM) is used as a tool. This tool is used to monitor the manufacturing process of PSB shovel in the shovel-manufacturing department.

Problem definition

The main aim of this research is to collect the value adding and non-value adding operations by using the tool VSM. In order to map the current state of the manufacturing process visual monitoring and manual data entry is necessary. In a job shop data entry for VSM can be complicated due to fluctuating cycle time for every work piece. Operators have to adapt to the order and the specification and manufacture according to the demands of the customer. The tools used in general for the operations are very basic, such as grinding machine, welding machines and different grinders. Monitoring these tools for their uptime is a complicated process.

Due to the above mentioned challenges for implementing lean in a HMLV there is no universally accepted methodology. The lean management concept is taken into account and modified according to the process, literature review and the available tools.

Purpose

The main ideology of the research is to club best ideas from the researched literature and experienced production manager. There is very little literature and framework for mapping VSM for a job shop process. The lean tools used like VSM paves the path towards approaching the problems. The reason for implementing lean in the production facility was because of the huge human involvement and unstandardized processes. Lean manufacturing helps address these problems in a job shop by using the VSM as lean manufacturing tool. To apply the VSM tool the right way in the present environment, it needs stringent understanding of the process. After the study of the process, monitoring the process is carried out to find the waste. These wastes can be identified by relating it to the “Toyota’s 7 types of waste”.

Due to its difficulty, monitoring the job shop environment and keeping track of every non-value adding operations at the same time can be a hard job to do. Therefore lean tools such as VSM are used, which the first and foremost step taken to detect non-value adding operations. Using Value Stream mapping in High mix and low volume is entirely different from the Toyota’s environment. Therefore changes needs to be made in the traditional VSM and implemented to track the waste in the Shovel manufacturing process. In the future the HMLV industries will be prevalent because of its high versatility in the manufacturing field. Therefore it is necessary to develop a standardised VSM for Job shop in HMLV environment.

Research Question

- 1) What sort of problem does one face, while implementing lean ideology in a High-Mix and low volume industry?
- 2) How can lean ideology be implemented in an “Engineer-to-order”, High-mix and low volume industry?
- 3) What Value stream principles can be used to map the future state for a job shop in a HMLV industry”?

The reason for choosing the respective research questions is because of the complexity of the implementation of lean principles for Job shop environment. The first research question focuses on the differences between the basic lean thinking and ETO environment. It tries to solve the confusion between the basic Toyota lean thinking and ETO environment. The second research question focuses on applying Toyota lean principles with some basic tailored value stream mapping. It shows the degree of difficulty in applying lean methodology. The third research question focuses on the improvement possibilities of the monitored process by applying suitable lean principles on the future state of the process.

Delimitations

Value Stream mapping usually is carried out for the entire organization from order to deliver. In this research the scope of study is limited to the PSB shovel production department from cut parts for shovel to the completion of the shovel. Shovel production being a hand job production Value stream mapping plays an important role. One of the reasons for limiting the area of scope is because of the limitation of the time. Lead-time of the complete mixer is around 6 months. The value stream mapping of other departments apart from shovel production is out of scope and avoided. The implementation of the future state is avoided due to insufficient time and lack of PSB shovel orders.

THEORY

Job Shop

Job shop is the place where human involvement is huge. The operations carried out should be performed on certain machines. These operations can be performed manually, on machine and also can omit some of the machines (De.wikipedia.org, 2016). Job shops are sometimes a huge problem due to its dull quality, huge lead times and excessive costs (Ashton and Cook, Jr., 1989). Job shops are common in manufacturing industries like aircraft, machine tools and construction equipment. These industries are low volume and “Engineer-to-order” industries, where the product mix variation depends on the customer’s requirement (Ashton and Cook, Jr., 1989).

Some of the problems job shop environment faces are reconfiguring of the machines, training of people for specialized product manufacturing, rescheduling of the work orders. This can lead to frustrated managers who would just accept the problems and live with it (Ashton and Cook, Jr., 1989). Changes in the job shop environment can be made but it requires foundational change in the management’s philosophy and knows how to use the workers more productively (Ashton and Cook, Jr., 1989). Monitoring the work flow of the workers in a job shop is a hard job unless every moment of the worker is monitored, which is an impossible task. The workers in the job shop due to their vast experience find easier ways to execute the job. Therefore the standardized procedure should be changed according to the worker.

Job Shop Manufacturing	Automated Manufacturing
Larger human involvement	Less Human involvement
Unreliable quality	Reliable quality
Less Control	More control
Fluctuating cycle times	Stable cycle time
More flexible and easy to change	Less flexible and harder to change

Table 1 – Comparison between job shop manufacturing and automated manufacturing.

High-Mix Low-volume Industries

The current research is carried out in an industry with wide range of product variety and low production. The aim of this research is to reduce waste and improve the process of shovel production. Toyota's automotive line production is a famous example for reducing waste, and the credit goes to Taichi Ohno (Lane, G. 2008). Toyota's high volume production is the only known and publicized concept for lean production. Due to variations in the product tradition lean tools cannot be directly applied in a high mix and low productions “Engineer-to-order” industry. However some lean tools can be tailored according to the situations of the

production (Lane, G. 2008). For a better understanding of the ETO companies and line production comparison is made below (Refer Table 1).

Line Production Environment	ETO, HMLV Environment
About 100,000-1,00,000+ units annually (Jina, Bhattacharya and Walton. 1997)	20-20,000 units annually (Jina, Bhattacharya and Walton. 1997)
Mass production with low variety products	Produces low volume with high variations products
Batch size is decided by the manufacturers	Batch size is decided by the customer
Demand can be planned and forecasted	Demand is forecasted after customers order
Production is standardized due to mass production	Due to high variation standardization is minimal
Line production with standardized workflow	Work flow is scrambled due to product variety
Less Overhead	More Overhead
Delivery time does not vary	Delivery date may vary due to imbalance in workflow.

Table 2 - Difference between Line and HMLV manufacturing

As the research carried on is an “Engineer-to-order” industry it is very important to define the Customer Order Decoupling point (CODP). CODP is defined as “the point in the material flow where the product is tied to specific customer order” (Olhager, 2011). It can be placed anywhere from inside of the manufacturing process to outside of the manufacturing process at the suppliers. The basic choices for placing the COPD are “Made-to-stock”, “Assemble-to-order”, “Make-to-order” and Engineer-to-order”. Lödige being “Assemble-to-order” the COPD is placed before the engineering COPD. Some of the COPD can be Engineer, fabricate, assemble and deliver (Olhager, 2011).

High-mix and Low-volume industries are different from the mass production industries. HMLV industries have large number of “active parts” and different services. These parts and services have very few demands forecasts and ever changing job descriptions. The orders are never predictable and thus the production cannot be planned before the order. The production planning takes place right after the order of the customer (Lane, G. 2008). For a better understanding HMLV industry, this is also termed as “Engineer-to-order” industry. These types of companies do not stock the products and produce wide range of products according to the customer requirements (Lane, G. 2008). As stated earlier in HMLV industries customer decides the batch size to be produced rather than the manufacturer in mass production industries. Due to this the production is just-in-time; therefore the important variable to be controlled is time (Lane, G. 2008).

As the HMLV has wide range of products and product families the “work order flow” is very complex. Mapping the value stream can be a difficult task especially in a job shop environment, where every operation depends on the requirement of the customer. VSM for this kind of job shop environment is not an impossible task. Data is critical in this mapping because every succeeding operation depends on the customer requirements and the experience of the worker (Lane, G. 2008).

According to Greg Lane (2011) it is common for managers to come to a conclusion early without proper monitoring of the process. It is human's nature to work with the more exciting layouts first than the lower and smaller layouts. In a job shop environment scheduling can be a huge task because the resources among the workers are shared and the demand is usually unknown before the order (Lane, G. 2008). In this situation “Takt time” (“time available/customer demand”) usually does not apply due to above states conditions like unknown customer demand and available time differs respectively with unstandardized product (Lane, G. 2008).

Value Stream Mapping

Value stream mapping (VSM) is a process of showing the actions carried out in the process. These actions can be both “value adding and non-value adding” in the production and design flow. Value stream mapping covers the process from very start of the process till the end. It is useful for the lean managers to implement concept lean in their production or design process (Rother and Shook, 2003).

Value stream mapping is a way of understanding the information and material flow from the supplier to the customer. The information flow is drawn on the upper part of the map, whereas material flow on the lower side (Rother and Shook, 2003). Keeping track of the entire production path and presenting every process in the information and material flow is carried out in VSM. It is preferably carried out with the valuable contribution of lean managers, experienced lean consultants and the employees. Although VSM needs experienced personnel, executing it with wide range of discussions with the production manager will provide enormous knowledge about the process (Rother and Shook, 2003).

Rother and Shook (2003) states some benefits of VSM as a tool and it is also the reason for choosing

- It helps to see the whole process at “single-level”, which means processes like welding; grinding etc can be seen all together.
- VSM is a great tool to find waste in the process and the source of the waste and can also be used as a language to discuss about the manufacturing process.
- It is a combination of many lean techniques and concepts and is a “basic implementation” plan for the whole “door-to-door operations.
- It also shows relation between information and material flow
- It provides the lead time, cycle time, changeover time, setup time, inventory amount etc. these numbers allow the personnel to make changes in order to create flow and adjustment to increase efficiency.

Olhager, (2011) states some of the drawbacks for mapping the value stream for ETO manufacturing.

- The Value stream mapping does not deal with the complicated value streams, where the product and process routing structure are complicated.
- For developing the lean flow only basic guidelines and techniques are used. Complicated and sophisticated tools should be available for mapping the complicated future state.
- The CODP is not defined or considered while drawing the future state. Positioning the CODP is critical for the performance of “Engineering-to-order” manufacturing. It should also asses the manufacturing and engineering lead times.

Material and Information Flow

Material and Information flow is an important and a crucial part of any operation and VSM provides a link between them. Usually it is assumed that material flow is the important aspect in the door-to-door process of manufacturing. It is not the case, with the Toyota manufacturing information flow is as important as the material flow because it tells the worker to how, what and how much to make according to the requirements.

Before starting to map the value stream of the process one has to define the product family. This will help to sort the operations, which are common for the entire product family.

Required Data for Mapping

The data for mapping the value stream from ordering of the material to delivering to the customer is essential. The following is the required data according to Rother and Shook (1998).

- Product family matrix: the list of the operations the products go through. For example welding, grinding, aligning etc. This family matrix allows the value stream manager

to select the product stream, which goes through out the same operations as other products. This makes the value stream standard for the other products and the future state can be applied for other products as well.

- List of the information pertaining to product information like: shift time, working time, breaks and monthly working days.
- Customer requirement is crucial because the manufacturing is carried out on the demands of customers.
- Information flow related to the job description, job deployments and production requirements to the other sectors of the production.

Principles for Lean Future State Map

After mapping the current state, it is necessary to immediately think about the future state of the production. Current state without a future state is useless. In order to make the future state lean and remove non-value adding operations Rother and Shook (1998) have suggested some principles, which are given below.

- Takt time: It is really important to calculate the takt time of the production process. This allows the manager to measure the efficiency of the manufacturing process.
- Stagnated products in the inventory are the sign of inefficient production line. Therefore planning the production process in such a way that there is continuous flow between the operations is necessary.
- Using supermarket control indicates the upstream process that the product has been withdrawn and alerts the upstream worker to make replenish the batch.
- To control the lot of the supermarket system FIFO pull system can be used. This provides the lot a specific number. This can inform the upstream process worker when to start producing the products to maintain continuous flow. FIFO also informs the upstream worker to stop producing if the batch size is full.
- Assigning the pacemaker to the downstream process right after the supermarket pull allows the whole production run continuously. If the production is perfectly managed at the pacemaker process sets the pace for the upstream processes.
- Producing mixed variety of products can lead to satisfying the customer who needs variations in their products. By leveling the production of different products can decrease the lead-time and inventory time. This can also lead to large changeover times and need to place the variation parts in the line of production.
- Create small and consistent increments of pull this will help the production flow to be predictable, easy to access the problem and find the solution also avoids uneven work done on the work pieces. Some disadvantages of large work increments are, no takt time sense, burden on machine and worker, shuffling of work orders, avoids reacting to customer requirement.
- Design the work order per shift or order, this allows the upstream production to respond to the changing downstream production.

RESEARCH METHOD

The methodology used for the research is divided into three parts. The methodology starts with study of products, learning the process ends with analysis of the process. The study of the products includes understanding the products classification and the produced variation in the product. In order to understand the process learning and understanding is critical. In the end after the Value stream-mapping analysis of the process is done.

Research Paradigm

According to Dr. Nirod K. Dash (2005) Educational research is all about exploring and understanding the phenomena surrounding us and pertaining to formalize the occurring social, cultural, physiological process that can be termed as education. This deals with the satisfactory educational questions, which leads to satisfactory investigation. This satisfactory investigation leads to results, which need no more investigation. Thomas Kuhn (1962) defines the term ‘paradigm’ as “An integrated cluster of substantive concepts, variable and problem attached with corresponding methodological approach and tools”.

Remarkable growths in social science research lead to the evolution of many research paradigms. The three main paradigms are positivism, anti-positivism and critical theory (Refer table 2). This research being quantitative research positivism as the research paradigm is adapted.

Positivism

A French philosopher August Comte, emphasized that ‘observation’ and ‘reason’ for understanding the behaviour of human beings. This particular paradigm is based on the philosophical ideas of Thomas Comte (Dash, 2005). He believes that knowledge can be obtained by ‘observation’, ‘experimentation’ and is based on the “experience of the senses”. Many researchers to create knowledge use positivism as a research paradigm. Therefore the assumptions made should be within the assumptions of science (Dash, 2005). According to Conen et al (2000) the assumptions are ‘deterministic’, ‘empiricism’, ‘parsimony’ and ‘generality’.

‘Determinism’ is the cause of events by other situations and ‘circumstances’, this is important because it is used for ‘prediction’ and ‘control’. “Empiricism is the collections of empirical evidence for supporting the hypothesis and theories”. Parsimony means “describing the phenomena in the most economical way”. “Generality means generalizing the observations made to the wide range of audience” (Dash, 2005). From the following assumptions the goal is to put forward a systematic system in a meaningful pattern, which is ‘tentative’ but not the truth. According to Dash (2005) “Positivistic paradigm thus systemizes the knowledge generation process with the help of quantification, which is essential to enhance the precision in the description of parameters and the discernment of the relationship among them” (Dash, 2005).

Research Paradigm	Research Approach	Research method	Examples
Positivism	Quantitative	<ul style="list-style-type: none"> • Surveys: • Longitudinal, • Cross-sectional, correlational; • Experimental, • Quasi-experimental and • Ex-post facto research 	<p>-Attitude of distance learners towards online based education</p> <p>-Relationship between students' motivation and their academic achievement.</p> <p>- Effect of intelligence on the academic performances of primary school learners</p>
Anti-positivism	Qualitative	<ul style="list-style-type: none"> • Biographical; • Phenomenological; • Ethnographical; • Case study 	<p>- A study of autobiography of a great statesman.</p> <p>- A study of dropout among the female students</p> <p>- A case study of an open distance learning Institution in a country.</p>
Critical Theory	Critical and action oriented	<ul style="list-style-type: none"> • Ideology critique; • Action research 	<p>- A study of development of education during the British rule in India</p> <p>- Absenteeism</p>

			among standard five students of a primary school
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Table 3 - Selection of research paradigm and research methods (Dash, 2005)

Company and Product background

Gebrüder Lödige Maschinenbau GmbH is a medium scale manufacturing industry with 252 employees. Lödige GmbH is famous for its Ploughshare Mixer and they have a history of first one to invent plough mixer (Ploughshare Mixer). They have been manufacturing special machines for around seven decades. Ever since then it is the leading process equipment provider in the field of Life sciences and Mixing and reacting technology (Lödige, 2016). Lödige is an “Engineer-to-order” industry with fluctuating and varying orders from customers. The list of machines Lödige manufactures is for different industries and processes. Some of them are arranged below (Refer table 3).

Life Sciences	Mixing and Reacting	Processes
Pharmaceutical Industry	Building material	Mixing
Food Industry	Cellulose	Drying
Cosmetics	Chemistry	Reacting
	Plastics	Coating
	Metallurgy	Granulating
	Minerals/ores	Emulsifying
	Starch	
	Environment	

Table 4 - Lödige’s manufacturing field

Lödige is divided into Office, Manufacturing and testing area. The office area consists of people who work in sales, project management, Design, Production planning and documentation department. The manufacturing area consists of Drum manufacturing, Shovel

manufacturing, Accessories fitting, Assembly area and Packaging area. Whereas the testing area consists of standard machine testing area, where different standard machines are installed and run for the costumer.

Plan

Task Name	Start Date	End Date	Duration
Duration	01/11/16	06/06/16	106d
Phase 1	01/11/16	02/02/16	17d
Meeting Production Manager	01/11/16	01/12/16	2d
Selection of topic, Hand-in, Project agreement	01/13/16	01/20/16	6d
Litrature review	01/21/16	02/02/16	9d
Phase 2	02/03/16	03/18/16	33d
Literature on the topic HMLV	02/03/16	02/08/16	4d
Learning to See by John Shook	02/09/16	02/26/16	14d
Practice VSM on PSS shovel	02/29/16	03/08/16	7d
Data Collection & Draft Preparation	03/09/16	03/18/16	8d
Phase 3	03/21/16	06/03/16	55d
Literature review & Data Collection	03/21/16	04/07/16	14d
Monitoring PSB shovel	04/08/16	04/26/16	13d
Value Stream Mapping	04/27/16	06/03/16	28d
Current State	04/27/16	05/02/16	4d
Future State	05/03/16	05/10/16	6d
Documentation	05/11/16	05/23/16	9d
Revision	05/25/16	06/03/16	8d

Figure 1 – Grid view of Project schedule

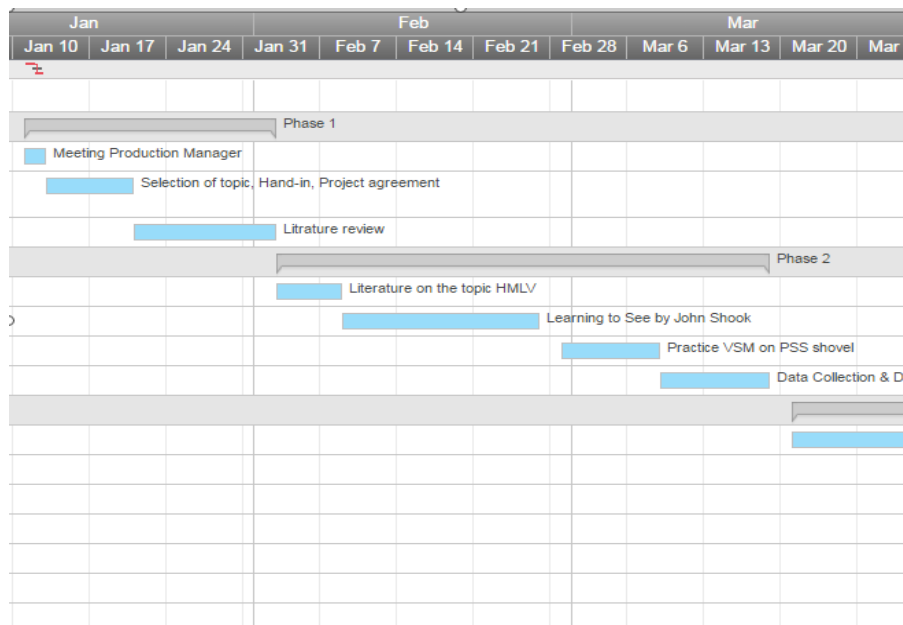


Figure 2 – Gantt view of the project schedule (January-March)

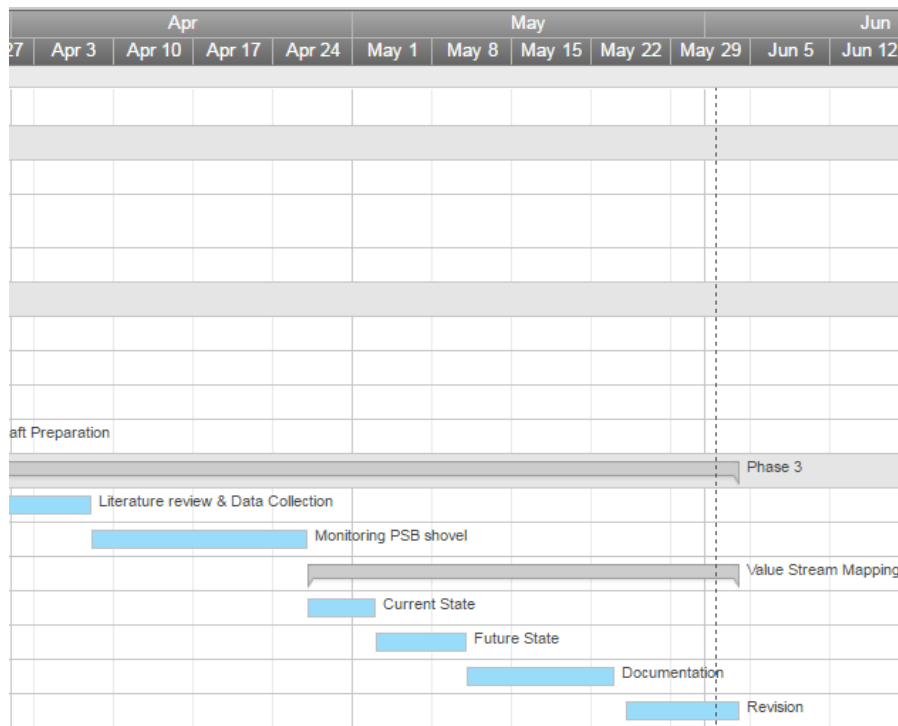


Figure 3 – Gantt view of the project schedule (March-June)

Area of Focus.

The area of focus for mapping the value stream is the shovel department. The reason for choosing the shovel department was because of huge human involvement. The scope for finding the inefficiencies are higher where human involvement is present.

- Manufacturing
- *Drum manufacturing*
- ✓ *Shovel manufacturing*
- Pre - assembly
- Final Assembly
- Quality Control
- Packaging
- Machine testing.

Current situation and Objective (Shovel Manufacturing)

The shovel-manufacturing department (2070) has 6 cabins, with a single blue-collar worker assigned in each and every cabin. The workers are well experienced and have an average of 20 years in experience in the shovel manufacturing. Every worker is equipped with shovel controlling mechanical device, Metal inserted gas machines (MIG), pneumatically powered hand held grinding machine, contact grinding machine, workshop vice and Gas welding. The list of devices is given below.

Customer Requirement

The customer here is the assembly department, they require 12 PSB shovels. As this company is an “Engineer-to-order” industry the order can range from 1 to 4 machines as a single order. Therefore the customer in the assembly department requires 4 sets of shovels. The shipment depends on the lead-time of the machine manufacturing. The customer can change his requirement depending upon his product of mixture.

Description of PSS and PSB Shovel

Parts

The first picture indicates the parts for the FKM 3000D full shovel and the second for the Half shovel. In the first picture starting blue marked parts, are called shovel plates. Right next to the shovel plates is the attaching plate and right below both the parts is retaining plate (refer appendix A table 1).

PSS shovel

A Standard Ploughshare shovel (PSS) are of two types, half shovel and full shovel (Refer Appendix A, Figure 4). Full shovel consists of an arm, side plates, upper plate, lower plate and bent rod. Due to its design and variations handwork is very critical. Materials in which the shovel is manufactured in are stainless steel and steel. The stainless steel can vary depending upon the customer's demand and requirement. Full shovel is a three-dimensional triangular sharp edged base and shovel arm. The Arm is attached on the top of the triangular shovel base. The base of the full shovel is made with two side plates, upper and lower plates and a retaining plate. Whereas in half shovel base is usually one sided and require only the half plate of the full shovel. These shovels have arms depending on the diameter of the cylindrical drum.

Ploughshare shovel rotates inside the cylindrical drum with a special arrangement on the horizontal shaft. In Lödige one of the keys aspects is that the coordination of size, number, positioning, geometry shapes, and peripheral speed inside the cylindrical drum is as per the three dimensional movement. Due to this type of shovel the fluid bed created allows for the material inside to mix without any static points. Hence the mixers with ploughshare shovels are suitable for mixing particles with different particle sizes, densities and mass fraction. In special cases, where addition of liquid is required, additionally driven choppers are used to help the mixing effect.

PSB Shovel

PSB shovels are similar to the PSS shovel except for its base and the retaining plate (Refer Appendix A, Figure 4). In PSB shovel the shovel base is already ready-made. Whereas the base of PSB shovel is assembled by the operator. Like PSS, PSB shovel also has half and full shovel. PSB full shovel consists of an Arm, attaching plate, full shovel plate and retaining plate (Refer Appendix A, Figure 6). Whereas the PSB half shovel consists of arm, half shovel plate and pocket plate (Refer Appendix A, Figure 7). They are manufactured both in stainless

steel and steel. The number of PSB shovel can vary depending on the capacity of the machine. Apart from the difference in the design structure of the PSS and PSB shovel, they both are used for mixing different products. One the big design qualities of PSB shovel is the retaining plate attached on the arm.

Gather Product Classification

Lödige shovel are one of the kind due to its perfection to specifications and the quality output. There are two types of shovels, full and half shovels. Further the full shovels are divided into PSS, PSB, PS-ERZ and the half shovel into PSS and PS-ERZ (Refer table 4). PSS shovels are the phoughshare shovels, which were invented by loedige (Refer Appendix A, figure 4). PSB shovel are the shovels monitored for this research, whereas PS – ERZ are the shovels, which are sent back to the job shop for repairs and refinishing. They are usually used shovel sent to make them better are they were before.

Full shovel	Half shovel
PSS	PSS
PSB	-
PS - ERZ	PS - ERZ

Table 5 - Types of shovels

The classification and the amount of shovels produced are given in the bar diagram (Refer Appendix A, Figure 1). This data is based on the sales of last three years 2013 to 2015. In total the combined full and half shovel are 306 and 185 respectively. The following data is classified into the shovel type, cylinder diameter and arm length (Refer appendix A, Table 1, 2 and3).

This analysis does not show any standardized product, the customer requirement differs for every shovel. Number of manufactured shovels according to customers requirement are 306. The PS shovel comes around 16 in number, which constitutes 72% among all the shovels (Refer Appendix A, Table1). The shovel concentration for full shovel is with the diameters is on 630, 790, 950, and 1110 (Refer Appendix A, Table 2). Whereas the concentration for half shovel is at 790, 950 and 1110 (Refer appendix A, Table 3).

The chosen product type for Value stream mapping is PSB shovel. PSS shovel being the most produced product over time. The schedule of PSS shovel did not meet with the planned dates for the thesis. Hence the next common product was selected, which is PSB shovel.

Product Family matrix

Family matrix shows types of products undergoing different operations while manufacturing. The family matrix for produced shovels by lödige is given below (Refer table 5)

Type/Operation	Align	Basting	Welding	Grinding	Check	Final Grinding
PS	Included	Included	Included	Included	Included	Included
PSS	Included	Included	Included	Included	Included	Included
PSB	Included	Included	Included	Included	Included	Included
PS-ERZ	Included	Included	Included	Included	Included	Included

Table 6 - Product Family Matrix for the Products Manufactured

Manufacturing Operation Description

Product name: - FKM 3000D

Variation: - FKM 3000D with PSB shovel.

The customer can choose whichever shovel needed depending on the mixture in the cylinder. It is either decided by the customer or advised by the company regarding the type of shovel.

Aligning

Base aligning is a process, which is operated manually by an operator. The setup time includes the operator entering the time stamp, selecting the mould for the aligning plate. The operator with the help of the forklift selects the mould from the stock and transfers it on to the aligning device into his cabin. The mould is further tightened and the side plates of the shovel base aligned. Base aligning operation is similar for all the shovel products manufactured. This process is the critical process because of its complexity. The tolerance of shovel base can change depending on the successive operations. It is necessary for the operator to align the shovel according to the given specifications.

The operator cleans the surface of the mould with a cleaning spray, calculates the base breadth and length and marks it on the surface mould with the permanent marker. Operator then places the side plates on the mould and checks for the specified tolerance level. If the tolerance level is accepted then the operator moves on to the succeeding operation. PSB half shovel is aligned in the same manner as the full shovel

Basting

Basting for is a joining process of the two metal plates of the shovel. Basting holds the parts in a position for the further welding of the part. The operator bastes the plates right after aligning the side plates according to the mould the tolerance. Basting process depends upon the design structure of the shovel base. Basting for both the process is done by MIG welding machine and the shovel base is placed on the wooden logs, Mechanical vice or Positioning system. Basting is done for the rest of the parts as well. Starting from attaching plate, full shovel plate, retaining plate, half shovel plate and pocket plate.

Welding

Welding of the basted shovel base is the successive process after base basting. Welding of the shovel base is carried out by the Cloos Quineo (MIG) Welding machine. The operator uses MTS positioning system to hold the shovel in the desired position. Complete welding is performed on the every attaching part to the shovel arm after basting.

Grinding

It is a pre-grinding operation, which is carried out right after the welding operation is completed. The operator uses Atlast Capco Hand held Grinding machine with korn grit 40 to grind the shovel. This operation is also carried out on every part, which has been welded to the arm of the shovel.

Check

The check process is the critical process in the shovel production. The operator places the shovel on the aligning device and checks the clearance between the shovel plate and the aligning plate. If the shovel clearance is according to the specified value then the shovel passes the check.

Final Grinding

This operation is performed right after all the shovels are pre-grinded. The operator uses three grinding machines. The used grinders are Atlas Capco vertical grinder; pneumatic die grinder and Suhner grinding machine. The desired grinding surfact is equal to or $>2\mu\text{m}$

Learning the process

An important aspect of Toyota production system (TPS) is to go see and learn. Commonly known as Gemba (“where work is done” in Japanese) session (Obara and Wilburn, 2012). A Gemba session is all about learning the process or the situation by physical presence. At the start making a “waste walk” started learning process; due to this a brief picture of non-value adding operations can be achieved. The reason for choosing the shovel department for streaming the value map is because of its product family. The operations carried out are similar for every shovel manufactured. The Gemba sessions taught the process advantages and disadvantages. In simple words the weak and strong areas of shovel department were learned. Strong aspect of the shovel department was its quality and one of the weak aspects

was the uneven workload. The lead-time for the shovel manufacturing was so high that other processes were in the inventory for a longer period than expected.

Process Description

Most of the operations in shovel production are hand work. As the operator receives the parts for the shovel production the following operations are performed as follows aligning, basting, welding, brushing and grinding. As the product specification changes on every order there is no standardized procedure for the production of the shovel. The Equipment used to perform the task is Control and aligning device, Welding machine, grinding machine and rest of the work is done by hand. The following operations undergoes in the PSB shovel production department (Refer Table 6).

No	Manufacturing Process
1	Setting the controlling Device
2	Record the relevant shovel measurement
3	Check the dimensions
4	Clamp the shovel arm in the aligning device.
5	Position the attaching plate and shovel plate and fasten it
6	Align the fastened connection on the shovel mould with the shovel arm
7	Baste the attaching plate to the shovel arm
8	Loosen the shovel plate from the attaching plate
9	Welding of the attaching plate with the shovel arm
10	Pre-grinding of the attaching arm
11	Align the arm with attaching arm
12	Clamp the attaching arm in the shovel arm aligning device.
13	Align the shovel plate with the Shovel arm in aligning device
14	Baste the shovel plate to the shovel arm
15	Weld the shovel plate to the shovel arm
16	Align the shovel

17	Grind the shovel
18	Clamping the shovel in the aligning device
19	Align and baste the retaining plates on the shovel
20	Weld the retaining plates on the shovel
21	Align the retaining plate and the shovel
22	Finishing grinding of the shovel

Table 7 - Manufacturing process of PSB full shovel

Draw the Value Stream map

To analyse the shovel production process value stream mapping used, because it presents systematic approach for monitoring any process from the beginning till the end. The reason for choosing VSM approach is to eliminate the non-value adding operations. VSM is a stringent process, the personnel creating VSM has to be present in the work place and take down the cycle time, changeover time, setup time and inventory. VSM is drawn using some standardised icons. However you can make some of your own.

Value stream mapping is a tool used by the managers for learning about the process. It can be said that it a language for communicating among the process managers (Rother and Shook, 1998). The way to excel in any new language is by practicing and applying it. Due to the practice the mapping gets easier every time you try it. To learn the process and practice the value stream mapping Ploughshare shovel were monitored and current value stream was mapped (Rother and Shook, 1998).

To develop the current state analysing current production situation is important. In this case PSB shovel case is presented where the current state is drawn from the start till the end. To draw the current state many standardised value stream icons are used. Every operation in this case is a complicated process because job shop has low automation process and more handwork. The cycle times differ for every product as well as the set up and changeover time. The time recorded for every product depends on the performance of the worker. If the worker thinks quality of the product is not up to the mark, changes will be made and one has to be alert in order to record the halts in the process (refer the). The following sets were taken into consideration to map the current sate mapping.

- The data collected for the future state was by walking along the material flow and the information flow
- As the production of the PSB shovel is one set of the variations in the shovel-manufacturing department and only one set of PSB shovel was being manufactured at

the time. This is the reason why instead of starting from downstream to upstream, data collection it is started from the upstream to downstream.

- Stopwatch is used to note the cycle time, changeover and set-up time.
- At first pencil and paper were used to map the stream, because it is easier to make changes later.

Drawing the current state map

The current state map is drawn on an A3 (11" x 17" size sheet) paper with the help of a pencil. The family product helps to identify the undergoing operations. In this case Aligning, Basting, welding, grinding, checking and final grinding. These operations are done on 10 full shovels and 2 half shovel. Among 10 Full shovels 8 of them have the retaining plate and 2 without the retaining plate. The 2 half shovels are similar to all the other half shovels (for example half shovel in PSS and PSB are similar, however the arm length and drum diameter can differ). The product matrix is given below.

At Lödige, to map the current state map the following data was recorded.

- Cycle time,
- Changeover time,
- Setup time,
- Number of operators,
- Product variation,
- Value adding time,
- Inventory,
- Non-value adding time.

Cycle time is defined as “time that elapses between one parts coming off the process to the next part coming off”; the changeover time is “time to switch from producing one type of product to another, which can be of same or different variation”; the setup time is the time required to prepare the device before performing an operation (Rother and Shook, 2003). The numbers of operators present were one, with one type of product variation. Value adding time is the duration of all the operations performed on the product to from the start till the end. Inventory is the place where the product stays after everyday production. Inventory time can be accounted as the non-value adding time on the production.

In the current state of the manufacturing process every shovel had fluctuating cycle time. Due to this the considered cycle time was the shortest of all the combined cycle times. It was observed that, shorter the cycle time of the shovel contains lesser re-works. Similarly longest cycle time has more re-works.

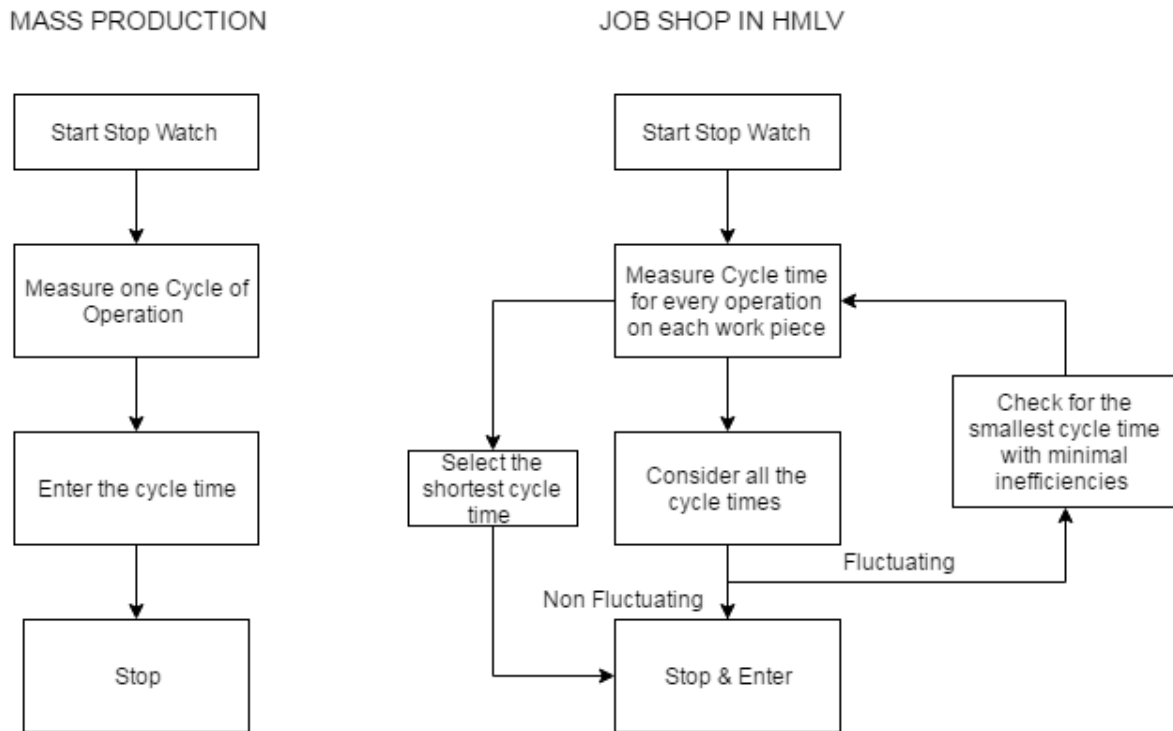


Figure 4 - Comparison of flowcharts for considering cycle time between mass and HMLV production

The Above figure (Figure 4) shows the flow chart for choosing the cycle time for the observed operations. All the cycle times for fluctuating operations were considered and among the fluctuating cycle times lowest time was chosen.

Conventional VSM for Mass Production	Improved VSM for Job Shops in HMLV
<ul style="list-style-type: none"> • Constant cycle time entered 	<ul style="list-style-type: none"> • Shortest cycle time entered
<ul style="list-style-type: none"> • Constant cycle time in timeline 	<ul style="list-style-type: none"> • Sum of all the cycle times in timeline

Table 8 – Comparison of Conventional VSM (mass production) & improved VSM (HMLV)

The table above (Table 7) shows the differences between the conventional value stream for mass production and improved value stream for Job shops in HMLV.

Reason for considering shortest cycle time

- The shortest cycle time is assumed to have less re-works compared to the other longer cycle times.
- This helps value stream manager to point the inefficiencies in the longer cycle times.
- It allows in measuring the approximate time required for every operation
- It is useful in mapping the future state.

Whereas the cycle time with large amount of re-works are because of the downtime of the welding machine, not able to find the fork lift when needed, improper division of tasks and unscheduled breaks.

Material flow

Due to the time constraint instead of mapping the current state of the complete industry only shovel manufacturing is considered. Initially the current state mapping starts with drawing the factory icon on the upper left top and data box underneath containing the inventory and requirements. The next step is drawing the production process of the PSB shovel. The process box is used to show the different processes. The process flow indicates the flow of material from Full shovel aligning to full shovel final grinding without retaining plate. Since the every process takes a large space on the map, process is condensed into:

1. Full shovel aligning
2. Attaching plate basting
3. Attaching plate welding
4. Attaching plate grinding
5. Full Shovel plate basting
6. Full Shovel plate welding
7. Full Shovel plate grinding
8. Retaining plate basting
9. Retaining plate welding
10. Retaining plate grinding
11. Full Shovel Check
12. Half shovel aligning
13. Pocket plate basting
14. Pocket plate welding
15. Pocket plate grinding
16. Half shovel plate basting
17. Half shovel plate welding

18. Half shovel plate grinding
19. Half shovel check
20. Half shovel final grinding (P80)
21. Half shovel final grinding (P60)
22. Half shovel final grinding (Suhner P60)
23. Full shovel final grinding (P80)
24. Full shovel final grinding (P60)
25. Full shovel final grinding (Suhner P60)
26. Full shovel final grinding without retaining plate (P80)
27. Full shovel final grinding without retaining plate (Suhner P60)

Worktime

The operator works at weekdays for around 8 hours without the breaks. There is only single shift with two breaks included, 15 mins for breakfast and 30 mins for lunch (Refer table 7).

Date	Time	Total Hours in Plant	Expected productive Hours (15+30 mins break)	Inventory
8.04.2016	6.00-11.15	5.15	5.00	
11.4.2016	6.00-14.30	8.30	7.45	2D 18H
12.4.2016	6.00-14.30	8.30	7.45	15H 30M
13.4.2016	6.00-14.30	8.30	7.45	15H 30M
14.4.2016	6.00-14.30	8.30	7.45	15H 30M
15.4.2016	6.00-11.15	5.15	5.00	15H 30M
18.4.2016	6.00-14.30	8.30	7.45	2D 18H
19.4.2016	6.00-14.30	8.30	7.45	15H 30M
20.4.2016	6.00-14.30	8.30	7.45	15H 30M
22.4.2016	6.00-11.15	5.15	5.00	15H 30M
25.4.2016	6.00-14.30	8.30	7.45	2D 18H
26.4.2016	6.00-12.30	6.30	6.15	15H 30M
Σ 12 Days		Σ 90.15	Σ 83.15	

Table 9 - Work hours by operator

Drawing Future state mapping

While drawing the future state mapping the following guidelines were considered (Refer Appendix A, Figure 11). The following suggestions are adapted from “Learning to see” by Rother and Shook, 2003.

Over production

Loedige being an “Engineer-to-order” industry there are very less chance for them to over producing the products. The area of focus shovel department manufactures depending on the customer orders. The overproduction aspect while manufacturing can be overlooked.

Takt Time

Takt time calculation tells at what rate the customer is buying the product. It is defined as the ratio between “available work time per shift” to “customer demand per shift” (Rother and Shook, 2003). Although the takt time allows stabilizing the pace of the production and improvement strategies, it is not always suitable for every production. For instance, at lödige the demand of customer is calculated on the batch size. There is no per shift demand. Even though we can calculate the takt time it is useless for high variation, low production industries. The reason is because of the variation and complexity in the manufacturing process.

However loedige provides the job shop with the run time. This is the time required by the worker to complete the required amount of shovel. The current run time is based on the statistics of the last 10 years of run time. Hence the run time/lead time provided by the design department is not based on the actual requirements for the process.

Continuous flow

Continuous flow is incorporated wherever possible to avoid stagnation among the three operators. For the future state instead of one operator three operators are appointed to finish the job. The future state is designed in such a way that category one needs half the duration of category two. Category three needs lesser time than category one. Whereas category four needs almost the same amount of time as of category two (refer appendix).

The mapped future state focuses on the flexibility of the workers. First in-First out (FIFO) approach is used between the four operating cabins. This allows the worker in the first cabin to stop producing the parts when the inventory is full and help the worker 3. Another value stream principles are “supermarket pull system”, the reason for not using the principles is because only one type of shovel was involved in the production (da CL Alves, 2005). Usually supermarket pull system is ideal for two or more different types of products. At the same time pacemaker process like supermarket pull system works successful where set up times are predictable and short, small batches of products with flexible production (da CL Alves, 2005).

Job Division

The concept of job flexibility is based on the discussions conducted with the shovel production manager. Also Lane, G. (2008) specifies the possible changes HMLV is to “increase flexibility to avoid the continuous bottlenecks”. The future state was mapped based on the divided work packages based on time and manufacturing steps. The work duration is divided among 3 operators in 4 cabins. Cabin 1 is assigned with the task of attaching plate, cabin 2 with shovel plate, cabin 3 with retaining plate and cabin 4 with the final grinding.

The task is only considered for the PSB full shovel. Future state of PSB shovel manufacturing involves 2, 4 and 1, 3 cabins with almost the same task duration. Whereas cabin 1’s duration is half of 2 and 3’s are half of 4. The work duration for 2 and 4 is double than the cabin 1 and 3 cabins. Therefore worker in cabin 1 can produce two shovels in the duration of cabin 2. Similarly cabin 3 can produce two shovels in the duration of cabin 2. The worker 1 works both in cabin 1 and cabin 3. The shovels are transported on the rolling band. The rolling band is located in between the cabins and follows FIFO control. The operator 4 does not have time to perform other activities.

The suggested future state mapping is designed in such a way that the work is divided into batches. This can help remove the high work pressure on the workers. It also introduces more strict tack time based on the work assigned.

Current state map	Future state map
No Control system	FIFO control system
One worker	3 workers
Produces only one variety in the given run time	Possible to produce more varieties in the given run time
Push system	Small and constant pull system.

Table 10 – Comparison of Current state map and future state map

Adopted Framework

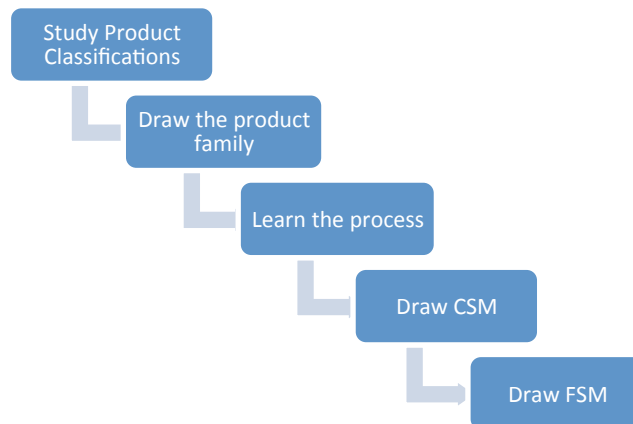


Figure 5 – Flow chart of adopted framework

The adopted framework is used to map the value stream of the PSB shovel manufacturing. The framework consists of 5 steps any value stream manager can follow before mapping value stream in a job shop for HMLV environment (Refer Figure 3).

The five steps are studying the product classifications, drawing the product family, Learning the process for deeper understanding, draw current state map and draw the future state map.

RESULTS AND ANALYSIS

Current State Mapping

The Value stream mapping starts with drawing the current state of the PSB shovel manufacturing. The current state is mapped from the parts entering into the shovel department till the finished PSB shovel is transferred to assembly department. The parts of the shovel are placed on the inventory rack for the worker to pick up. These shovels are then later placed near the job shop sub-inventory trolley. Later the worker divides the manufacturing process into Aligning, Basting, Welding, grinding of Full and Half shovel. Every part attached to Full and half shovel undergoes the mentioned operations (Refer Appendix A, Figure 10).

The manufacturing of the PSB shovel is carried out by one operator. The parts for the Full shovel are Attaching plate, Shovel plate and retaining plate. Whereas half shovel parts are shovel plate and pocket plate (Refer Appendix B, figure 4). The material flow data recorded in the Current state map are Cycle time, Changeover time. The information show recorded is the job assignment and time stamp. The tools required for operating on the shovel is given in a table (Refer Appendix A table 6). As mentioned above in the methodology section under “drawing current state map” shortest cycle time is entered in the current state. However the sum of all the cycle times is entered in the timeline of every operation.

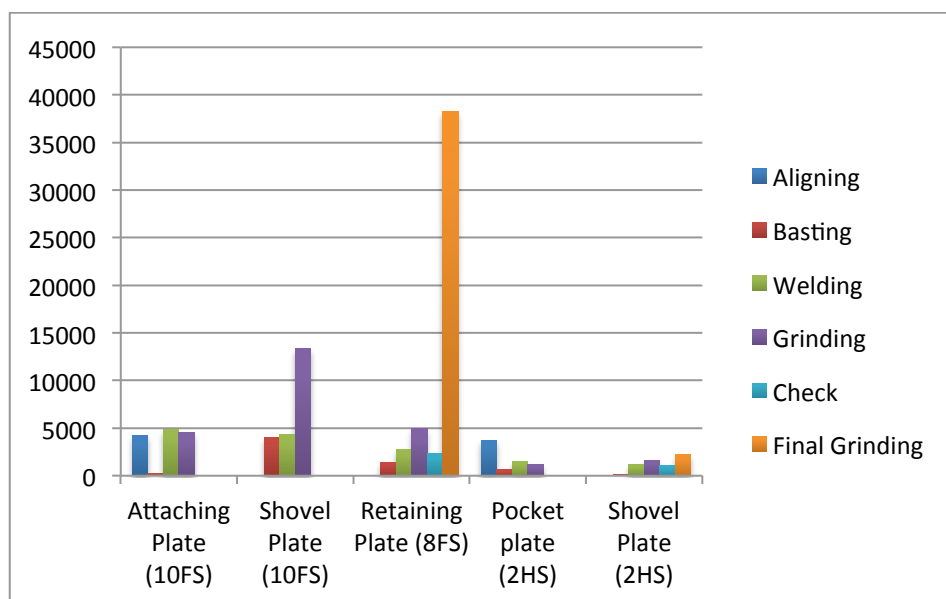


Figure 6 - Duration of each Operation with Final Grinding

The Current state map has provided information about each operation carried out on every part of shovel. The above figure (Refer Figure 4) shows that grinding of shovel plate is the second longest operation for 10 shovels and the final grinding of the full shovel is the longest of all the operations. Because the final grinding is the longest operation deeper analysis was necessary. This analysis shows the duration of grinding machine on the shovel (Refer Figure

5). Basting operation of full shovel retaining plate, half shovel pocket plate, half shovel plate takes shorter period of time compared to welding and grinding. Aligning of the full shovel and half shovel operation takes almost to 5000 seconds.

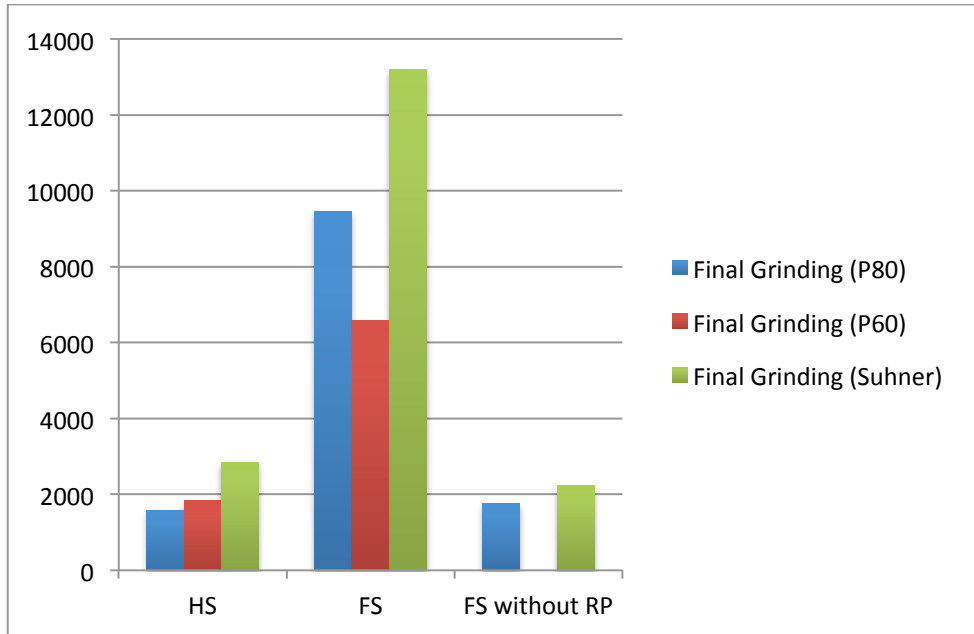


Figure 7 - Duration of final grinding in seconds (FS+HS)

The above figure (Refer Figure 5) indicates duration of Final Grinding operation carried on the PSB shovel. This analysis shows that, which grinding machine and plate is used the most. It is clear that Suhner Grinding machine is used the most on the both half and full shovels. By this analysis maintenance of the grinding machine can be scheduled to avoid downtime.

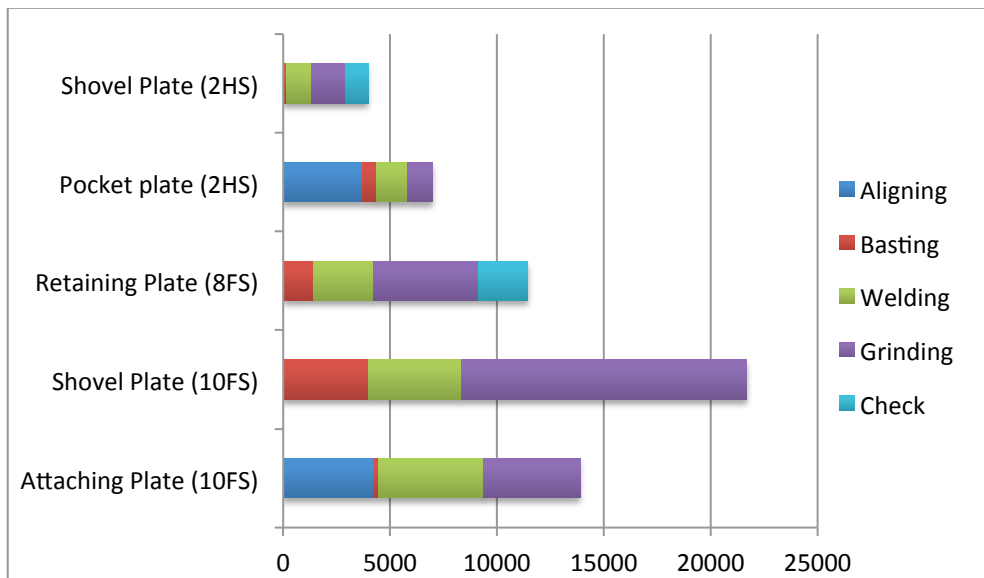


Figure 8 - Duration of Each Task for shovel parts without final Grinding.

The above figure (Refer Figure 6) shows the duration of each task divided respectively according to the order of manufacturing procedure. The table shows the time taken for every task to be performed on the shovel manufacturing. The shovel plate takes the most because of its large surface area, hence the operations performed also are longer. The attaching plate and retaining plate are taking up less time compared to the shovel plate. Whereas half shovel pocket plate and shovel plate take the shortest duration compared to the full shovel.

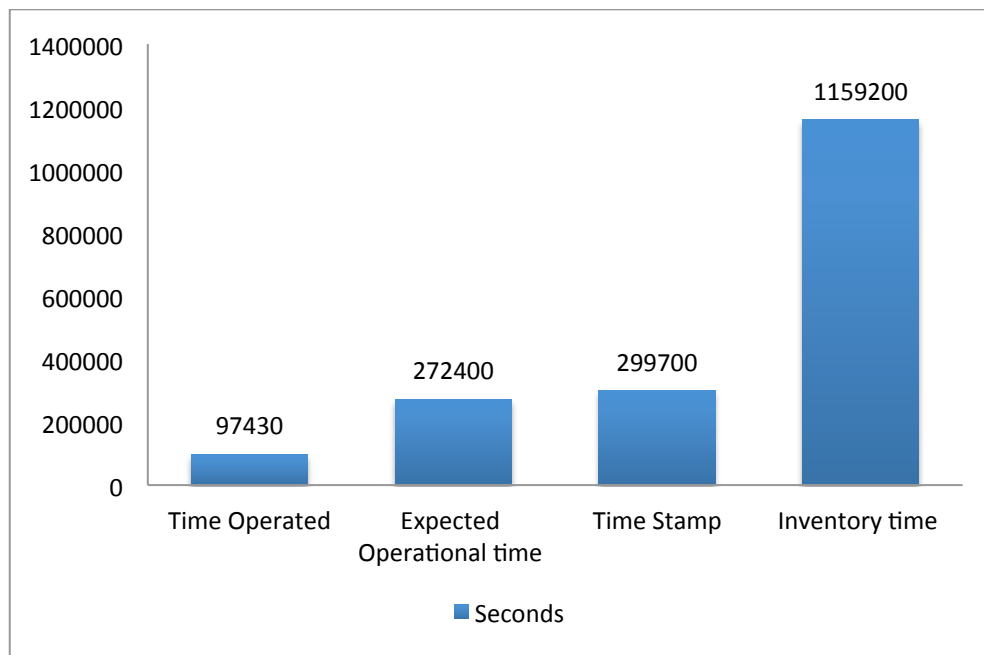


Figure 9 - Calculated final time for different variables (10FS+2HS) in seconds

The figure above (Refer Figure 4) shows the time duration of different variables calculated for the PSB shovel. This table shows the inefficiencies due to the non-value adding operations. The specified variables are time operated by the operator on the PSB full and half shovel, Expected operational time by the operator, and stamped time information by the operator and the lead-time of the PSB full and half shovel.

Future State mapping

The future state mapping was based on the data and analysis of the current state. The manufacturing operations are divided into four categories to be spread among the four cabins with each cabin containing an operator (Refer Appendix A, Figure 11). The four cabins and workers are designed after the aspect of single shovel and manufacturing steps.

The parts of the shovel reach the cabin 1; operator 1 performs his assigned job of attaching plate. The work piece moves forward to cabin 2 and the shovel reaches cabin 3 after the job at cabin 2 is completed. As the shovel reaches cabin 3, worker 1 leaves his cabin to perform operation at cabin 3. As soon as the FIFO rolling band lane is about to go empty the operator

1 returns back to cabin 1 to produce more and fill the FIFO lane. Finally after the operation at cabin 3 is finishes it moves on to the operator 4.

The cabin 1 takes approximately 13880 seconds to finish its job. The category 2 takes double the time i.e. 2367 seconds to finish the job. These two operations are carried out simultaneously. The category 3 and 4 follow the same with 1143 and 3322 seconds. The future state map is only considered for the PSB full shovel. After the discussions with the shovel department manager PSB half shovel were decided to manufacture separately with the other products because of its similar design structure.

Time operated (seconds)	97430
Expected operational time (seconds)	272400
Lost time (hours) = Expected operational time – Time operated	48.6 (64% loss)
Financial loss (€) = Lost time x pay per hour (€)	48.6x33 = 1603.8€

Table 11 – Loss incurred

The above table (Table 8) shows the time and financial loss by the industry on PSB 3000D shovels. Time operated is the time spent on the manufacturing of PSB 3000D. The manufacturing department provides the expected operational time. Difference between the expected operational time and time operated gives the lost time. The lost time constitutes to 64%, which leads to financial loss of 1603.8€

The motivation behind mapping the future state was to incorporate control and flexibility in the manufacturing process. FIFO control provides control in the process and job division provides flexibility. The suggested Future state is expected to save the time of shovel manufacturing.

REFLECTIONS

This research is carried out to answer the research questions in a qualitative way. The results are the end results of the research conducted.

- 1) What sort of problem does one face, while mapping value stream in a job shop for High-Mix and low volume industry environment?

The problems pertaining in a job shop can be several because of the involvement of the human activity. In job shop environment the workers are highly skilled because of the variation in the products and work is entirely by hand. High-mix & low volume industries are heavily dependent on the job shops because of their product variations. These products need human attention while the manufacturing is according to the customer requirement. If High-mix & low volume (HMLV) industries are compared to High Volume & Low Mix (HVLM) industries one particular crucial aspect they differ in is the hand work operations and the fluctuating lead time. The use of automation technology in HMLV is minimal in when compared to HVLM industries.

The area of research in this paper is the shovel manufacturing for the mixers. As mentioned above in order to make the shovel manufacturing efficient lean manufacturing methodology is chosen. As per the researched literature “Learning to See” by John Shook Value Stream Mapping (VSM) is the effective way to see the non-value adding and value-adding operations in a manufacturing process. To map Value stream Cycle time, changeover time and setup time are important and should be noted down. The problem with the cycle time was that every cycle time for the workpiece was fluctuating. It was one of the major problems faced while mapping the current stream mapping.

The reason for fluctuating cycle is because of the hand work. The operations performed on the shovel needs to pass the quality check by the operator himself. As observed in while manufacturing the shovel, operator starts the job at a slow pace and speeds up at the end. This led to bad quality, uneven clearance between the mould and shovel plate. Mapping future state for one product is ideal because it eliminates the uncertainties involving in between with the other products.

- 2) What changes are made in the value stream mapping, in order to map the manufacturing value stream for a job shop in High-mix and low volume environment?

Originally value stream mapping was developed for mass production industries. It is ideal for industries with high automation because the automated machines are more reliable and work with same efficiency all the time in certain conditions. Whereas in a job shop condition value stream mapping can be a huge task to perform. Some of the changes made in the current value stream are with the entering of the cycle time. The cycle time of every shovel was taken down and the lowest cycle time is entered for every operation.

The reason for doing so was to see the least cycle time required by the operator. The chances of non-value adding operations are low in the shorter cycle times. However the entire time required for the shovels to undergo every operation are summed up and put down in the timeline. This will help to analyse the time operated by the worker on the shovels. The importance of shorter cycle times is that they can be used to analyse and prepare the ideal future state map.

- 3) What Value stream principles can be used to map the future state for a job shop in a HMLV industry”?

The ideology used in the future state mapping is job Flexibility (to divide the job among four different job shops assigned to three workers). In order to make the manufacturing lean FIFO principle is used. This is used to control the upstream production so that there is no over production. FIFO also indicates the worker in the upstream process when to resume production. By controlling the upstream production between the cabins can be controlled and managed. The workers can help each other if the workload is huge and uncontrollable.

CONCLUSION

The reason for conducting this research was to detect the inefficiencies in the PSB shovel manufacturing process. The chosen tool to detect these inefficiencies is the Value stream mapping. The adopted methodology and framework was followed, which is based on the literature and acquired information from the shovel department. The following information acquired is used to select the product and to map the value stream. At first the current state is mapped with changes in cycle time and timeline of the process. This allowed finding the approximate duration of every task and operation performed on the Shovel.

The literature from “Learning to see”, discussion with the shovel production manager and data analysis helped in mapping the future state of the PSB shovel manufacturing. The future state focuses on job flexibility of the workers and reducing the manufacturing time by dividing the job duration among four different cabins with four respective workers. The current research shows the importance of mapping value stream in the job shop with necessary changes. It leads the path towards improved future state of job shop operations.

Scientific Contribution

Value stream mapping is originally designed for process monitoring with less human involvement and mass production. There are very less literature on the problems pertaining with the implementation of VSM in Job shop environment. This research focuses on implementing VSM in job shop environment and points out the problems faced. The problems are reflection section. The problems can be generalised to the entire job shops in HMLV industry based on the literature and information conducted.

Based on the aim of the research, as to avoid the problem while taking data some changes are made to the conventional Value stream mapping. These changes are done to find the duration of the operations and tasks of the shovel production. The data analysed from the Value stream shows the time operated on the shovel, which is less than half of the expected operational time. It can be said that VSM can be used as a tool to find inefficient in the job shop environment.

FURTHER RESEARCH

Due to the time constraint implementation of future state was not possible. The future state in the future should be implemented and verified if the principles suggested are possible. Generating takt time increases control on the job shop operators. This can be done by the ideology of day-by the hour (Lane, G. 2008). This concept can generate a strict takt time and possibly reduce inefficiencies of the manufacturing process. The suggested future state for the PSB full shovel can also have a strict tact time. Implementing it solves many problems and difficulties a value stream manager faces.

The other aspect, which requires further research, is to check if the Value stream mapping is applicable on the entire industry. Generate a standardised Value stream-mapping tool for the industry to reflect on.

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NB!

The attached appendix is missing from this publication.