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Application of Value Stream Mapping to Boost Productivity: A Case Study

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***Abstract* – In todays customer driven world, companies cannot afford to disappoint their customers by not meeting their demands. Thus to keep up with the customer expectations and the competition offered by fellow organisations, companies need to reduce the time/money they spend on steps which add no value to the entire process. Such steps can be called as 'waste' these waste steps just use up valuable time and money of the company but do not contribute towards the final product which the customers will eventually use. This paper intends to understand the concept of Value Stream Mapping (VSM), its challenges as well as a real time case study. The current and future state maps were created and the results were analysed. The paper also throws light on the concept of Lean methodology in the form of a brief literature review.**

Keywords: Value Stream Mapping, Literature Review, Case study, Challenges, Lean methodology, Cycle time reduction.

1. INTRODUCTION

In today's world companies are striving to achieve leaner and responsive methods in order to increase productivity and output of their operations. Lean methods focus on reducing processes which are invaluable in nature [1]. These processes are also termed as non-value adding processes. The term "Muda" in Japanese means waste, hence lean methods aim to reduce this Muda from processes. Organisations are greatly utilising lean methods to reduce their process cycle times. Many institutions use lean tools along with six sigma methods to optimize their cycle time. The only difference between lean methods and six sigma is that lean tools help to reduce the waste/unimportant processes, on the other hand, six sigma methods reduce variation in processes. When lean and six sigma methods are used together, they are termed as Lean six sigma. There are many lean tools but we will look at only a few of them. In this paper, we will be focusing on the concept of Value Stream Mapping aided cycle time reduction.

2. LITERATURE REVIEW- LEAN MANUFACTURING

Lean techniques were first introduced in Japan and were first used by Toyota [1]. In today's world, companies are striving to cope up with the customer demand, which is very high. In order to do so, these companies have to eliminate the waste in their processes. This waste or 'Muda' is/are nothing but non-value adding processes or activities which reduce the efficiency of the entire process. For example, non-value adding activities include- inspecting, waiting, walking, reworking, unnecessary movement etc. on the other hand, value-added activities include- Rolling, forging, machining etc. Thus Lean manufacturing focuses on reducing this waste. Costumers will be only willing to pay if their product is delivered on time and is flawless. There should be no space for error and delay. We can say that the ultimate goal of lean manufacturing is to manufacture products with the highest quality, at the least cost and in the lowest possible time. SWOT analysis can be used with lean processes to eliminate waste more effectively [1]. Using lean methods, Toyota used lean techniques after word war II to produce automobiles with low inventory, less effort and a very low investment along with negligible errors/defects. This also allowed them to introduce a greater variety of products. Thus lean manufacturing if well utilised by companies, can really prove to provide a competitive lead to the company using them as compared to organizations resorting to traditional manufacturing methods. The allied benefits of lean methods include boosting of employee morale, bringing in more innovation as well as effective communication and coordination amongst different parts of the process. Following table describes some of the basic lean tools in brief.

Table 1 – Lean tools (Definitions).

No.	TOOL	DEFINITION
1	Value Stream Mapping (VSM)	VSM is used to create a visual flow of all the required components needed to complete the process. The aim here is to analyse and optimize the process.
2	Just-in-time (JIT)	Manufacturers only go into production when the customers request or order the product. This avoids unnecessary stocking up of products.
3	Error proofing	Also known as Poke-yoke. It ensures that the correct conditions exist before the process commences. It is a prevention method.
4	Plan-Do-Check-Act (PDCA)	Used to manage change and to achieve continuous improvements in processes.
5	Overall-Equipment-Effectiveness (OEE)	It is used to measure productivity in manufacturing. It calculates the percentage of manufacturing time that is actually productive.

International Journal of Engineering Research & Technology (IJERT)
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6	Bottleneck Analysis	Bottleneck analysis is used to check for any areas or the exact points in the process that are causing the workflow to be slower than usual.
7	Root Cause Analysis (RCA)	This tool is used to identify the underlying root cause of a problem.

The concept of Lean manufacturing is customer demand driven. This means that unlike the traditional manufacturing methods, lean methods believe that the production should be demand oriented, which does not allow stacking up of huge inventories which may or may not get sold within the expected timeframe. Hence lean methods classify inventories as waste. Lean manufacturers can thus produce fewer products and bring them in the market in a shorter time as compared to traditional manufacturers thus gaining a competitive edge over others.

3. LITERATURE REVIEW- VALUE STREAM MAPPING (VSM)

Value Stream Mapping is one of the most powerful lean tools. VSM can be used to declutter complex processes in order to identify non-value adding activities which reduce the value of the entire process. Value stream in VSM defines the specific point in the process where the value actually gets added. Hence in simple words we can define VSM as a tool that combines product processing steps with information flow and related important data. In other words, VSM is basically all the steps which are needed to be taken, for a product/service to be taken from the raw material stage to a finished product stage. VSM allows the organization to create a visualisation of all the steps involved in their processes, which represents the flow of goods from the supplier to the customer throughout the organization. It allows the organization to visualize every step in the process and gives a quick status update to the team just by a single glance. The main purpose to create a value stream map is to indicate places or points in the process which can be improved. This can be done by visualizing value-adding as well as non-value adding steps. Thus only by having a glance at this map, an in depth analysis of all the steps involved in the process can be done, thus giving the team the ability to make changes in the process to make it more efficient by eliminating waste. VSM also suggests improvements which can made in the future. Following are some of the symbols used in VSM, relevant to the scope of this paper:

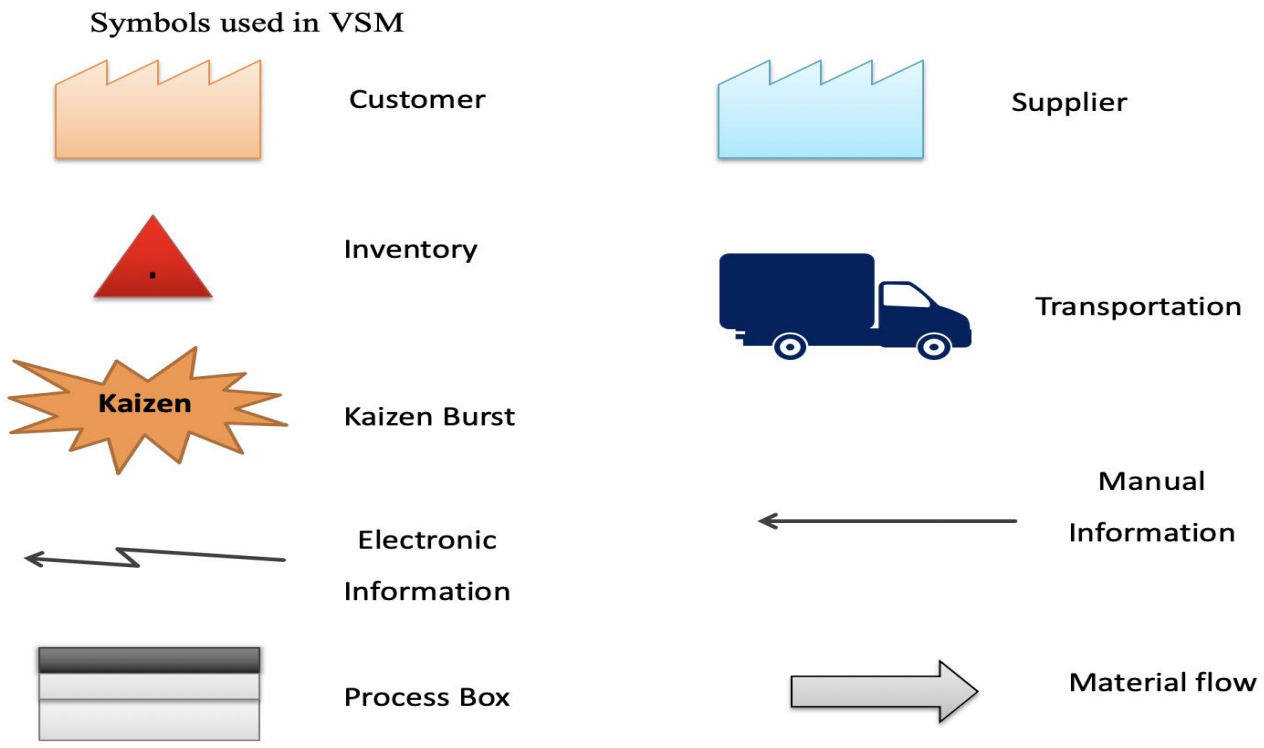

Fig.1. Symbols used in VSM

Value stream mapping can not only be used in manufacturing but can be applied to a variety of domains. For instance, VSM can be utilized in supply chains to remove/prevent wasteful delays which reduce the efficiency of the supply chain. Further, VSM when applied to the health care industry can prove to improve the way in which the patients are treated, i.e. to treat patients in the most effective way. Inefficiencies in software development procedures and the need to rework can be reduced using VSM, right from idea to implementation. In value stream mapping, the process items that flow through the stream are mainly determined by the industry domain or field. For example in manufacturing processes, materials used will be the items, in the service industry,

International Journal of Engineering Research & Technology (IJERT)
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external customer needs will be the process item, in the administration domain internal customer requirements will be the item, in the design and development domain, designs will be the process item.

The value stream technique can be elaborated as follows:
VSM as described before, is all the steps -value added and non-value added ,which are performed to complete a process which develops a product or service right from the start to the end. It involves numerous processes and functions. It is thus important to have all the entities involved in the value stream, i.e. users, customers and operators to be involved in improving the process. Since VSM is a method in which the production path of the product is mapped visually, it is very easy for the operators like suppliers, engineers, management and even the customers to point out the waste and identify their root cause and thus eliminate such wastes. VSM visually maps the process flows, like the flow of information, materials etc, in a timely manner. It considers all process flows from raw materials to finished products. We can now list down the major pros of Value Stream Mapping as follows:

1) Helps identify all non-value adding processes and helps reduce wastes and improves the efficiency of the process.
2) Provides a visual mapping approach, hence it makes it very easy to identify wastes.
3) Priority processes are thus given more importance thus accelerating growth.
4) Increases customer satisfaction.

To understand the VSM process better, following are all the steps to implement VSM [2]:

A) *Determining the Value Stream:* This step deals with identifying the value stream to be enhanced. Thus involves a deep analysis and many efforts taken to understand the limits of the mapping activity.

B) *Developing a Current state Value stream map:* This map shows the current state of the process being examined. It can be described as an 'as-it-is' form of the process, which still has all the inefficiencies/wastes [2]. It shows how things work currently in the organisation. The current state value stream map thus makes it easy to point out the wastes that currently exist in the value stream.

C) *Making the Future Value Stream map:* This step intends to create a value stream map which aims to reduce wastes or non-value added processes. It is thus a 'future map' which proposes the ideal value stream for the process and successfully meets customer requirements efficiently and increases productivity. It incorporates all improvements needed in the current process to achieve the ultimate goal or the vision of the value stream.

D) *Creating the improvement plan:* This means that to achieve the future value stream map, certain improvements are to be made. Thus these are the set of improvements which ensure that the proposed future value stream is achieved. This is the final step in the VSM process [2].

In order to understand the concept of VSM in a more effective way, we will now create a value stream for a real life problem and try to reduce the cycle time of the process using the concept of VSM. Thus a future value stream map will be created for the process, finally achieving the ultimate value stream vision, thus also achieving maximum customer satisfaction.

Before understanding the problem statement of this case study, following are some of the basic concepts used to apply VSM and come up with a solution [4] :

A) *Cycle time* : Cycle time is the actual time spent working on producing an item or providing a service, measured from the start of the first task to the end of the last task. Cycle time includes both value-added time as well as non-value-added time.
Hence we can say that ***Cycle time = Net production Time/No. of units produced.***

B) *Takt Time:* Takt time is the rate at which the company needs to complete a product to meet customer demand. It is a tool used to design work and it measures the average time interval between the start of production of one unit and the start of production of the next unit when items are produced sequentially. For calculations, it is defined as the time taken to produce parts divided by the number of parts demanded in that time interval.
Thus, ***Takt Time = Total Available production time/Average customer demand.***

C) *Lead Time:* A definition of lead time is the time from the moment the customer places an order (the moment the supplier learns of the requirement) to the moment it is ready for delivery.
Lead Time = Order Delivered - Order Received.

4. THE PROBLEM STATEMENT

The manufacturing process of the part 'Deutz Head 8047' was analysed at Aakar Foundry Pvt. Ltd. It was observed that the cycle time of the part was quite less than the takt time, due to which the monthly customer demand of "Concentric Pumps Pvt. Ltd." was easily met but because of the cycle time being less than the take time, there was unnecessary inventory and over production seen. This in turn created excessive lead time, resulting in high storage costs and thus making it difficult to detect defects. Due to the current layout of the plant at Aakar Foundry Pvt. Ltd. there was a lot of non-value added time seen in the form of waiting, reworking, transportation of raw material and the part between two processes. Due to this there was also a Difficulty in tracing a particular part between two processes.
All these shortcomings showed a need to correct the current stream map by introducing constructive improvements.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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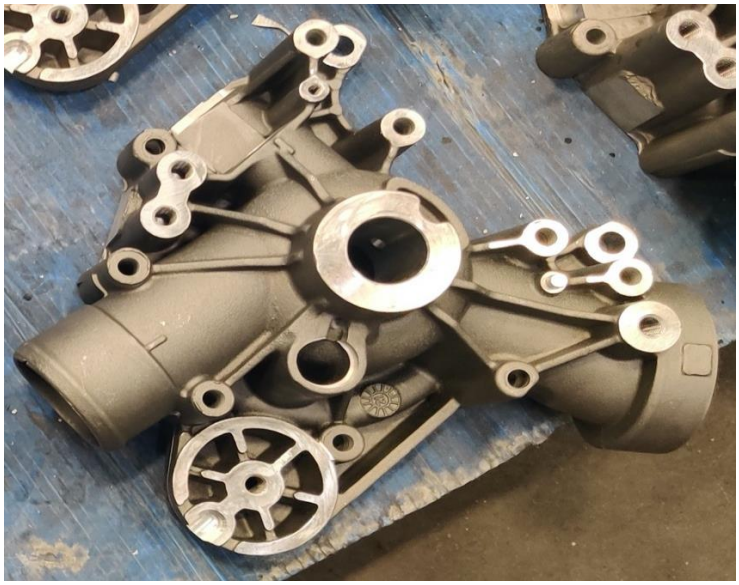

Fig.2. Deutz Head 8047.

5. OBJECTIVE.

The objective of this case study is to reduce the storage time of the part "Deutz Head 8047" in the inventory thus leading to the reduction in storage cost and avoiding unnecessary inventory. Also the goal here is to increase the productivity of the process, which can be achieved by relocating the workers appropriately to different manufacturing processes. Further a very important quality of an effective process is a reduction in costs. This cost reduction is targeted here, by eliminating workers wherever possible as in this case, the customer demand is met with ease. A new plant layout to be created for Aakar Foundry Pvt. Ltd. to reduce transportation time or raw materials and the time between any two processes.

6. METHODOLOGY.

The research methodology used in this paper is a case-study strategy. Understanding the concept of Value Stream Mapping might seem easy theoretically, but in actuality it is very complicated. An engineer can only enhance his skills with experience and by tackling real life situations to solve problems. Hence we decided to collect real-life data to solve a very real problem faced by an industry. Data was collected and compiled to understand the problem in an effective way. Initially a specific part manufactured by this company was selected for value stream analysis, the next step after selecting the part was understanding the problem statement. As mentioned earlier, the cycle time of the part was quite less than the takt time. To analyze its implications, data was collected which comprehensively described the entire process to us. This data was tabulated depicting the cycle time, changeover time and number of workers employed for each step for the entire process. Using this data, the cycle time, takt time and lead time for the current process was calculated. Using these calculations, the next step was to create the CSM or the current state map, which described the process in its current state. That is including the value and non-value added processes. This current stream map pointed out the wastes and discrepancies in the process which were to be removed to achieve the goal. The required improvements were suggested and an FSM was made. That is, a Future State Map. Which depicts the final process after all the wastes are removed, or the non-value added processes were eliminated. An in-depth analysis of this Future state map was done, thus finally achieving the targeted goals. This method of research, i.e., a case study path has definitely proven to be an efficient way to understand a concept. Research findings in the form of a case study give rise to new ideas for improvement in that domain.

6.1. Data collection.

The necessary data was collected depicting number of workers, cycle time and changeover time for each process involved. The collected data was organized in a tabular form to analyze it.

Table 2- Data collection.

Process	No. of Workers	Cycle time	Batch	Changeover time.
Casting	2	3+1 mins	1	2 mins
Cutting	1	32 secs	1	15 secs
Sandering	1	45 secs	1	10 secs
Fettling	1	1 min	1	10 secs
Shot Blasting	1	10 mins	80	10 mins
Machining	3	10+10+4 mins	1	3 mins
Impregnation	1	60 mins	40	5 mins
Leak Testing	1	5 mins	1	15 secs
Washing	1	4 mins	1	15 secs
Inspection	1	3 mins	1	10 secs
Dispach	3	3 mins	2	10 secs

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

6.2. Current Plant layout and CSM.

After data collection, the current process to manufacture the part Deutz head 8047 was analyzed. The current plant layout describes the current sequence/flow of processes that takes place to manufacture this part. Looking at this flowchart, and comparing it with the data table, we could make out the time taken for each process in detail. Fig.3 shows the current plant layout.

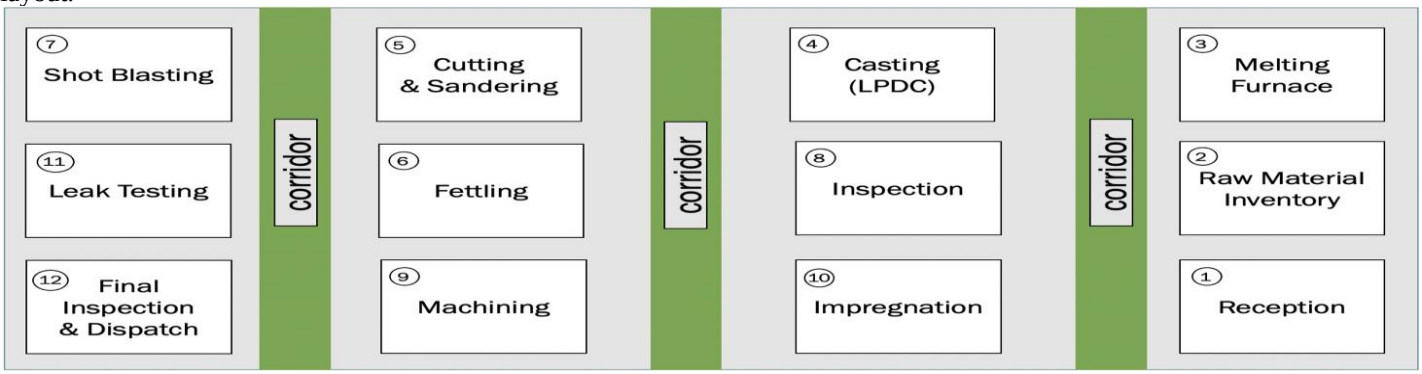

Fig.3. Current Plant Layout.

Now, the CSM is given as:

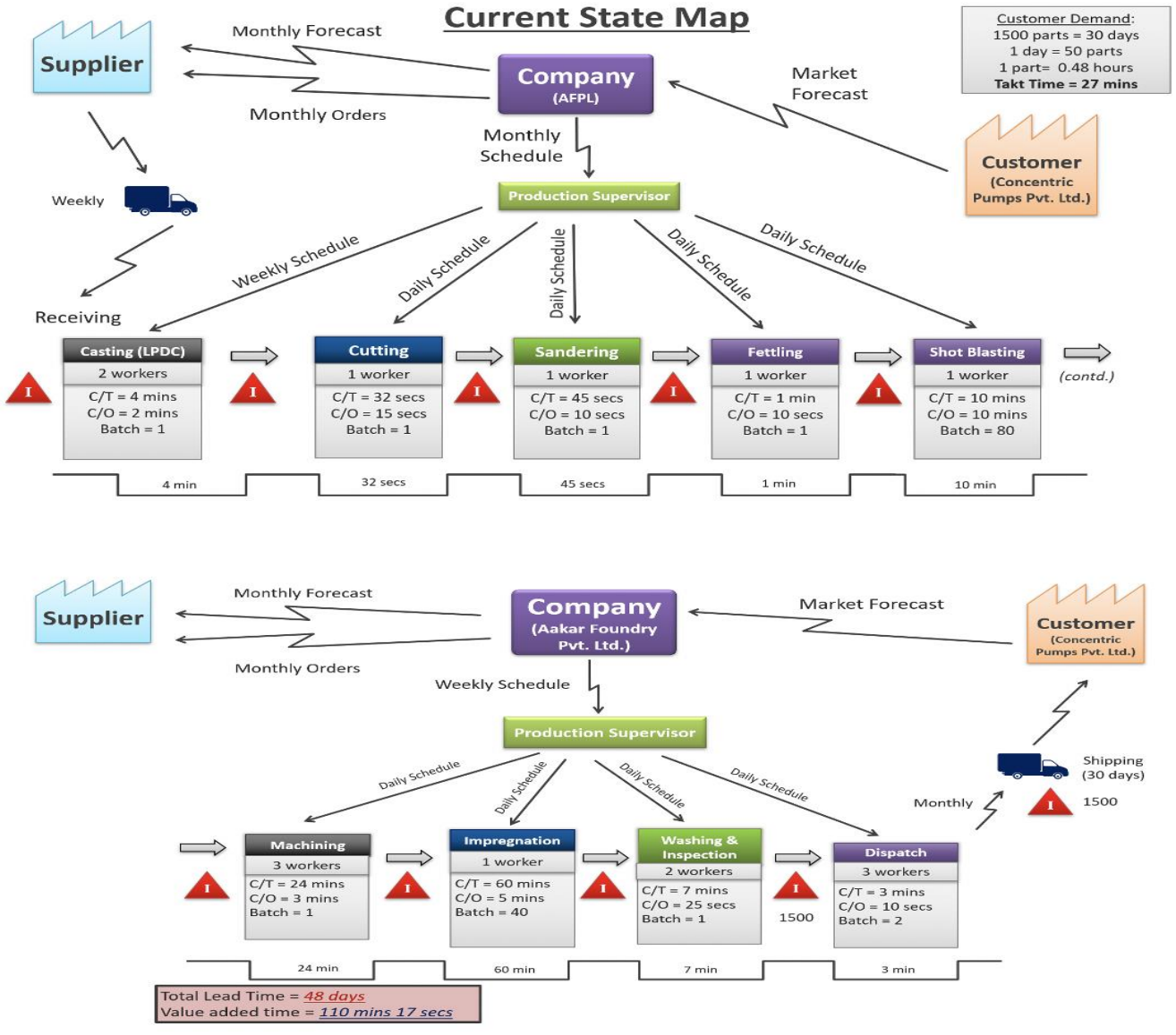

Fig.4. CSM

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

To use the VSM tool to suggest improvements in the current process can only be done when an accurate CSM is made. As discussed earlier, CSM shows the current state of the process. That is including all value as well as non-value added processes. The main task here is to identify the processes which are waste, which could be removed or improved to achieve the ultimate goal. The CSM in Fig.4 can be explained as follows:

1. The cycle time of the entire process was found out to be less than the calculated takt time. This is an ideal case scenario and thus no bottlenecking takes place at any of the manufacturing processes.
2. After calculations, an excessive lead time was observed. This excessive lead time resulted in high storage costs and made it difficult to detect defects in finished goods.
3. As the cycle time is much less than the calculated takt time, over production is observed at certain instances and it leads to unnecessary waste during inventory.
4. High non-value-added time is observed in the form of transportation of raw material and goods from one station to another due to current plant layout which leads to waste.
5. A shortage of workers was observed at certain manufacturing stations on the shop floor. A single semi-skilled worker was carrying out tedious processes like shot-blasting and impregnation.
6. These processes are carried out in batches and take additional setup time to be carried out on the shop floor. Due to a single person carrying out these processes, idle time for these machines is high and it reduces overall productivity of the system.

Based on the above analysis, a Future state map and a future plant layout was suggested.

6.3. Future Plant layout and FSM.

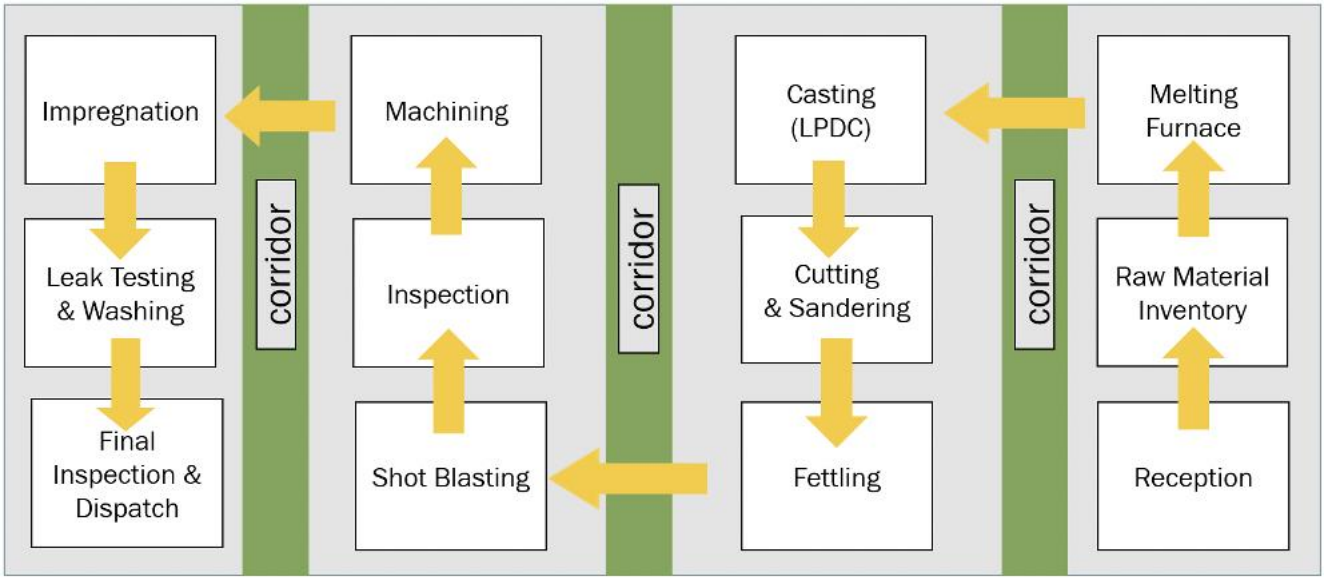

Fig.5. Future Plant layout.

The new plant layout can be analysed as follows:

1. The current plant layout at Aakar Foundry Pvt. Ltd. does not ensure a continuous process flow of the raw material and unfinished goods on the shop floor.
2. Due to this, a high downtime was observed on certain occasions due to ‘no load’ for the machines.
3. In order to combat this issue in future, a new plant layout was suggested at the end of our project thesis.
4. The new plant layout ensures a continuous process flow of raw material, unfinished goods and finished parts to the dispatch stage.
5. It was designed after taking into consideration many factors concerning the possible issues that can be faced at any given time frame on the shop floor.
6. The new design reduces waste in the form of transportation of raw material and the part from one station to the another, indirectly reducing non-value added time and increasing productivity.

The future state map for Aakar foundry was developed. Fig 6 shows the FSM.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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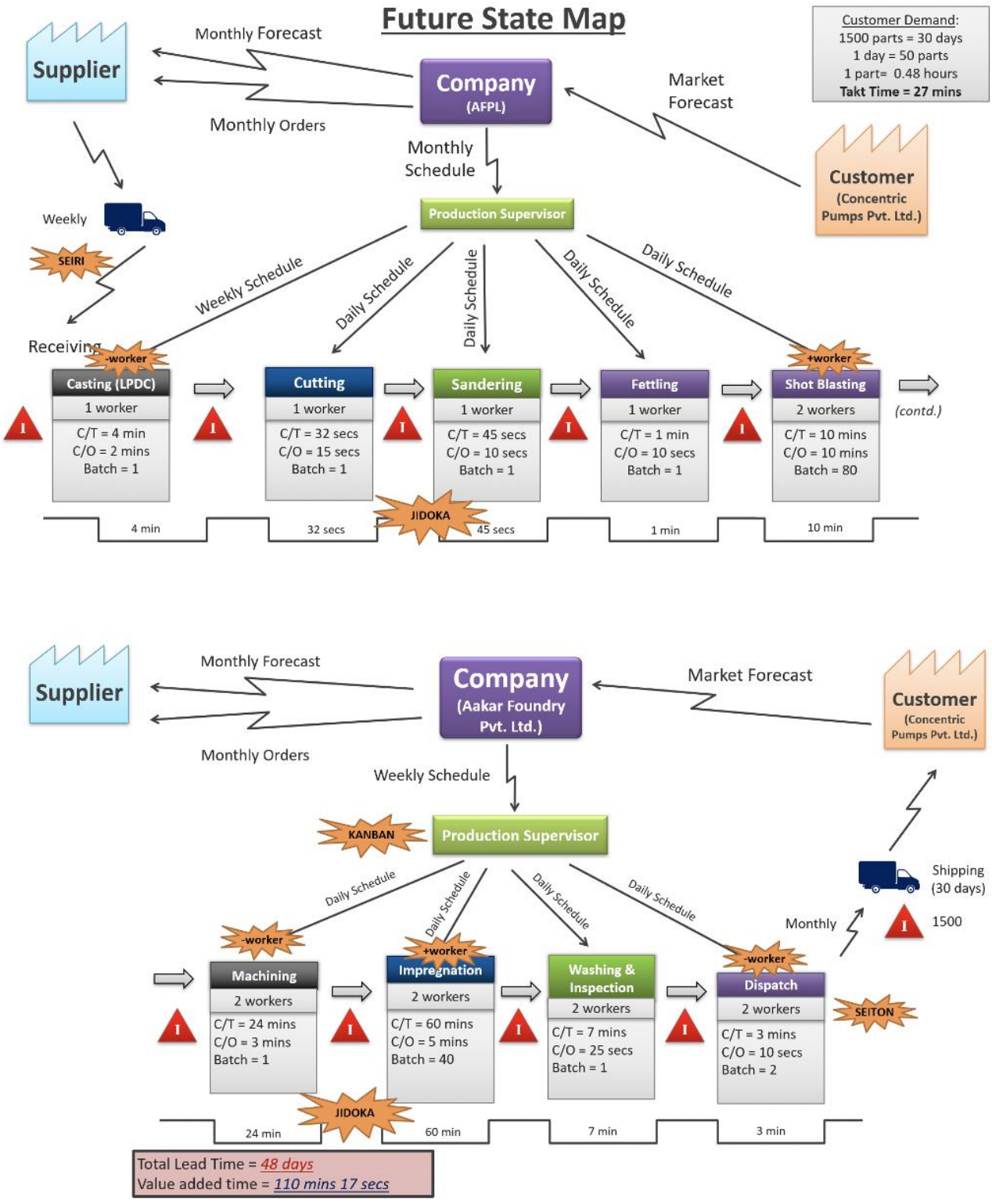

Fig.6. FSM

The FSM suggests constructive changes in the current process of manufacturing Deutz Head 8047, thus making the process efficient by reducing wastes. The FSM is analysed as follows:

1. Implementation of '*jidoka*' for transportation of raw material and goods between two manufacturing process stations. '*Jidoka*' is a word of Japanese origin which stands for automation. It is a key pillar in the Toyota Production System (TPS) and is widely used in lean manufacturing.
2. In lean manufacturing, implementation of *jidoka* means to separate people from machines and thus automate the entire system.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

3. Implementation of 5s (*Seiri*: sort) in the raw material inventory in order to avoid confusion between different types of alloys which are used for the casting process.
4. Implementation of 5s (*Seiton*: set in order) of the unfinished parts between two processes in order to eliminate the difficulty of tracing the parts.
5. Installation of '*Kanban*' boards at each station to help tracking of parts for frequent checks at the quality control department.
6. Removal of the additional worker(s) from the Machining, Casting, and Dispatch stations. These processes can be carried out smoothly with the help of a single skilled worker at the station.
7. Distribution of the additional workers to Shot Blasting and Impregnation stations where the setup time is more and productivity can be increased.
8. Implementation of the new plant layout to reduce transportation time between two processes and increase productivity.

Thus the FSM shows that the process has been successfully optimized to meet the requirements of the company and thus prevent overstocking of inventory. Even though VSM is a very powerful tool to improve a process, it still has its fair share of drawbacks. The next section of this paper discusses about the various challenges or limitations of Value Stream Mapping.

7. CHALLENGES IN VSM.

As mentioned throughout the paper, VSM is definitely a very useful tool to eliminate non-value adding processes, thus increasing the efficiency of the process and meeting customer expectations. VSM as is a boon, could also be a Bain. VSM can complicate the process of identification of non-value adding activities, and could also make the process being examined, more inefficient by adding waste. VSM executed in a company on a hands-on process completely depends on the skills of the employee handling the mapping process. Then the future of the mapping process only depends on the knowledge of that employee and how he/she analyses the current process and plans out its future. **Liker et al 2005** say that VSM cannot be used blindly as a fool proof solution to solve industrial problems. The skill of carrying out a flawless VSM process only comes with practice and handling various complex situations. Hence this tool should be used wisely. **Dal Forno et al 2014** have categorised various cases in which VSM could go wrong. These cases become the main reasons for the failure of this lean tool. The paper has reviewed 57 research articles including case studies as well as theoretical review papers on VSM [6]. Following are some of the reasons described:

1) VSM has been observed to fail in unstable processes. These include those processes in which the operating parameters do not remain stable. That is the mapping cannot be done properly and the process cannot be improved because every day, the behaviour of the process changes. This calls for realizing the importance of standardization of processes. For the mapping process to work, the process being examined has to be stable that means to maintain in cycle time stability, meeting the predefined procedures, constant manufacturing processes, repeatability and reproducibility should be ensured by using reliable machines that can also maintain the defined quality levels. Thus processes should behave with consistency over a period of time to define them as stable.
2) Collecting data is the most important step in the value stream mapping process. Properly collected data shows a clear image of what needs to be done to improve the process. When this data is improperly collected, or is not accurate, then even if the process is stable, it is of no use. As bad data will mislead the mapping process and might also create new problems. The best way to ensure an effective data collection is the transparency of the organisation.
3) The next challenge in the mapping process arises with complexity of the product [6]. Thus when we consider the manufacturing process of a complex product, for example an assembly of a product, which has many parts, then the process of identifying value and non-value adding processes becomes very difficult. Further the flow of the process also becomes complex to distinguish while mapping the process. Identifying a complex product involves naming all the individual parts, the manufacturing procedure of all those parts, their specifications etc. hence with complexity, more challenging becomes the mapping process.
4) The Lean philosophy believes in continuous improvement. This improvement can happen at any time interval, hence the company has to update its value stream along with improving its systems, as product life cycles become shorter day by day with the increased customer expectations, the VSM process must be repeated regularly to keep up with the technological/information updates the company is making. As if this is not done, the old VSM for the company becomes obsolete as new information sets emerge without a new VSM process form them. Repeating the entire VSM procedure takes time, hence very good planning has to be done so as to decide these time intervals when VSM should be performed.
5) Challenges also remain with humans handling the VSM process. Lack of skilled personnel can lead to a very ineffective value stream which might further hinder the process by adding wastes instead of removing them. The person who has been assigned the mapping process, must have an in depth knowledge of the same.

Thus the above arguments prove the notion that VSM cannot be categorised as a one time blind faith solution for all industrial problems associated with improving efficiency and productivity of the organization. It is definitely a very effective tool to do so but should be used wisely to obtain the desired results.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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8. CONCLUSION.

In this paper we have discussed the concept of Value Stream Mapping, also understanding the concept of Lean and six sigma in brief. The concept of VSM is indeed promising for organisations looking to optimise their processes. Wastes or non-value adding processes are the main contributors to inefficiencies, identifying these wastes and eliminating them is most important to optimize any process. This paper also took a real life case study of a company to optimize the process of manufacturing the part 'Deutz Head 8047'. The CSM and FSM for the process was created and the intended goal was reached. The case study aided to understand the process of implementing VSM in depth, even though the VSM tool has many advantages, there are still many limitations and challenges which cannot be neglected. These challenges were also explained in this paper. Thus we conclude that organisations should regularly take up the initiative to perform VSM analysis to ensure that their processes remain efficient and customer demand is met thus also insuring customer satisfaction.

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10. REFERENCES.

[1] [1] Shaman Gupta & Sanjiv Kumar Jain (2013) "A literature review of lean manufacturing", International Journal of Management Science and Engineering Management, 8:4, 241-249, DOI: 10.1080/17509653.2013.825074

[2] [2] Guo-quiang Pan, Ding-zhong FENG, Mei-xian JIANG ,"Application research of shortening delivery time through value stream mapping analysis" 2010 IEEE 17th international conference on industrial engineering and engineering management.DOI:10.1109/ICIEEM.2010.5646515

[3] [3] Serrano Lasa, I., Ochoa Laburu, C. and de Castro Vila, R. (2008), "An evaluation of the value stream mapping tool", *Business Process Management Journal*, Vol. 14 No. 1, pp. 39-52. https://doi.org/10.1108/14637150810849391

[4] [4] R Siva *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **197** 012064,"Process improvement by cycle time reduction through Lean Methodology" Link: https://iopscience.iop.org/article/10.1088/1757-899X/197/1/012064/pdf

[5] [5] Dinesh Seth & Vaibhav Gupta (2005) Application of value stream mapping for lean operations and cycle time reduction: an Indian case study, Production Planning & Control, 16:1, 44-59, DOI: 10.1080/09537280512331325281

[6] [6] Ana Dal Forno," Value Stream Mapping: a study about the problems and challenges found in the literature from the past 15 years a review" DOI 10.1007/s00170-014-5712-z

[7] [7] K. Boonsthonsatit and S. Jungthawan, "Lean supply chain management-based value stream mapping in a case of Thailand automotive industry," *2015 4th International Conference on Advanced Logistics and Transport (ICALT)*, 2015, pp. 65-69, doi: 10.1109/ICAdLT.2015.7136593.

[8] [8] Florin Buruiana, Mihaela Banu, A.M. Goncalves Coelho, Alexandru Epureanu, Alice Buruiana,"Value stream map and Kaizen concept implemented in a shaft manufacturing chain" (2009)