Application of Value Stream Mapping for Productivity Improvement- Case Study of a Foundry Industry

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Abstract— The term value stream mapping is defined as a lean manufacturing tool which includes all the actions both value added and non-value added required bringing a product into its finished state. In today's global competitive world, the era of mass production and pull system is over and companies are experiencing a heavy pressure because of globalization. Main objective of any organisation become satisfying customer requirements. Value is now defined by customer point of view as customer willing to pay and what worthiness that product has for them. They will not pay for any waste and companies have to be focused on this. Thus, companies need to implement Value Stream Mapping (VSM) because it has been established as one of the best and most convenient tools of lean manufacturing implementation and to identify and eliminate all kind of wastes. This paper presents a case study of application of value stream mapping in an Indian foundry industry. This industry was manufacturing Crusher Jaw plates. The application of these plates is in stone cutting plants. The case study has been used to show the applicability and importance of VSM in foundry industry. Current state of the jaw plate manufacturing has been developed by using VSM symbols. This current state map was then used to identify areas for improvements. From the findings of CVSM it was observed that lead time was quite high for given demand, Cycle Time was more than Takt time and number of operators could be reduced by combining operations. As a result, including individual improvements in WIP, Labour Utilisation, Cycle Time, Lead Time, Changeover Time, the overall improvement was found near to 22%.

Key words: Lean Manufacturing (LM), VSM (Value stream map), CVSM (Current state value stream map), FVSM (Future state value stream map), VA (Value added activity), NVA (Non-value added activity), Kaizen, WIP, Lead Time

I. INTRODUCTION

To ensure competitiveness in this high pressured continuous changing and developing market conditions, implementation of lean manufacturing is become necessary for organisations. Lean manufacturing is identified as a comprehensive set of much effective techniques for waste identification and its elimination from processes in order to enhance system flexibility, effectiveness, efficiency and reduce overall production costs. One of the most common and convenient way to implement lean manufacturing is the application of Value Stream Mapping (VSM). Before going to define VSM, we must understand what is value? Value of the product is measured at end users (customers). Value of the product for customer is in terms of money, satisfaction, performance, service or elegance. To serve the best value to the customers company needs a customer requirement data. This data become helpful to make a right product for right customer with right specification at right time with right price. To make this entire system correct VSM is the most common and helpful tool to make entire stream valuable and to eliminate non-value adding activities. Value Stream Mapping (VSM) is a set of methods to visually display the flow of materials and information. Whenever there is a product for a customer, there is a value stream and the change lies in the seeing it. Value Stream map is also known as "Material and information flow mapping" in Toyota. It is developed by a work carried out by Taiichi Ohno at Toyota in the 1960's - 70's. VSM doesn't require a tough and tedious work. It requires just a paper, pencil tool to draw CVSM and FVSM and brainstorming sessions for improvements and comments. In one project there are two value stream maps. A current state map (CVSM) and a future state map (FVSM). A current state value stream map shows what is the actual processing steps are at the beginning of a project. It identifies wastes and NVAs. The future state map shows what the process should look like at the end of the project? And how these processes can be improved? After these improvements as they are suggested changes in current system are made. Now, This FVSM will be the CVSM for next project. And this cycle continuously goes on. We can use VSM as a Lean method to identify the opportunities of improvements for future. VSM method is associated with production as well as with service sectors. It can be used for Reduction in lead and cycle time of various processes, Customer satisfaction and value addition, Managing supply chain activities, Development of efficient production techniques, Improving productivity and profitability, Layout and equipment modification etc.

This paper describes a case study explaining the successful implementation of VSM into a foundry industry. The product being manufactured is crusher jaw plate. Lean manufacturing is a widely accepted and applied technique in manufacturing industries and it has been cumulatively implemented all over the world by many leading organisations. Global competition among the industries is constantly arising and industries are facing very tough to face changes. To sustain changes they need changes and improvements in their system. For this adoption of lean tool is must. Lean Manufacturing is extensive and intelligent set of tools for waste identification and reduction or elimination from manufacturing processes to make them more effective, more flexible, and more efficient and reduce individual as well as overall costs of operations and product being manufactured. One of the most effective and convenient way to achieve all targets is the application of VSM on specified product family.

The VSM process is simple and straight forward. It includes all the areas starting from raw material procurement to the selling of final product into customer hands. Along with processes, it also includes customer

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demand, service levels and work back by documentation of all the necessary data required to manufacture a product.

Crusher jaw plate is a complex product to be manufactured in a foundry industry, it consist of about eleven major steps to be considered for study. The operations starting from procurement of raw material to raw material, melting mould and design making, core and pattern making, knocking, degating, grinding, fettling, quality inspection etc. the main aim of the industry was to reduce overall cost, lead time and increment in value added activities up to an acceptable value in economical manner. VSM has been selected based on questionnaire, personal meetings and discussing with managers and operators on floor. Production planning and control, sales and marketing, design and pattern shop has helped us to give past records about demands production volume, daily working time etc.

II. LITERATURE REVIEW

The term value stream first used by Womack, Jones and Ross in their book "the machine that changed the world"[1]. And later it was described thoroughly in "Lean thinking" by Womack and Jones[2]. Lean manufacturing uses tools like Poka Yoke, Kaizen, Standardisation, workplace organisation and waste reduction, Inventory management etc. to reduce manufacturing wastes. VSM is an excellent tool for any enterprise that wants to become lean. Rother and Shook (1999) defines VSM as powerful tool that not only highlights process inefficiencies, transactional and communication mismatches but also guides about the improvement. Jones and Womack explain VSM as the process of visually mapping the flow of information and material as they are and preparing a future state map with better methods and performance. Seth and Gupta have made a successful attempt to use VSM as a technique to achieve improvement in productivity at the supplier end for an automotive industry[9]. Over the years many lean manufacturing tools to support value stream have been developed and many more are being developed. The following table provides an overview of major contributions in the field of VSM.

MAJOR CONTRIBUTORS	**AREA OF WORK**
1. Womack and jones; 1996[2]	Defined thoroughly value stream mapping in book" lean thinking"
2. Hines (1999), Grewal and Singh (2006)	Identification and elimination of Muda
3. Brunt (2000) ;Abdulamek and Rajgopal (2007); Seth et.al.; (2008)[13]	Improved productivity of process industry
4. Tapping et.al.; 2002[6]	Defined VSM as visual representation of the material and information flow of a particular product family
5. Hugh L. Macmanus et.al.; 2002	Carried out VSM study in 9 major US aerospace agency and correlated various factors based on collected data
6. Seth and Gupta; 2005[9]	Productivity improvement at supplier end
7. Rhonda R.Lummus et.al.; 2006[10]	Applied VSM successfully at a physician clinic for quality improvement
8. Markus L. Stamm et.al.; 2008	Applied VSM successfully at manufacture to order at small and medium enterprise showing potential reduction in lead time
9. Seth et.al.; 2008[13]	Address various wastes in the supply chain of the edible cottonseed oil industry
10. Bhim singh and S.K.sharma; 2009[14]	Explained how VSM helps to bring the gap between current state and future state map and developed a road map to take improvement areas.
11. S.Vinod et.al.; 2010[15]	Applied VSM in Indian context in man camshaft manufacturing industry to enable leanness in that organisation
12. Duranik et.al.; 2011[21]	Applied VSM to find out hidden reserves and to avoid bottlenecks An idea of zero percentage waste was developed
13. Ritesh bhat et.al.; 2011	Deployed VSM along with KANBAN focusing on productivity improvement by considering a case study of gear pump manufacturing firm in Indian context and findings were reduction in production lead time and number of workers
14. Rahani AR et.al.; 2012[24]	Defined VSM in other words and defined that VSM involves in all processing steps to analyse NVA and VA as a visual tool to identify hidden waste and source of waste
15. R.M. Belokar et.al.; 2012[22]	Implemented VSM for process capability improvement of welding process. significant improvement was found as a result
16. Silva et.al.; 2012[23]	Applied VSM in SriLankan apparel industry with an objective to find out applicability in apparel industry.
17. Harwinder singh et.al.; 2013[25]	Applied lean manufacturing using VSM in an auto part manufacturing cell.as a result a major portion of cycle time, reduction in WIP and reduction in production lean time for targeted process.

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18. Naga Vamsi et.al.; 2013	Implemented LM using VSM as a tool in an auto component industry in India. Area of improvement in WIP, lead time, cycle time identified.
19. K.Venkataraman et.al.; 2014[29]	VSM applied in crankshaft manufacturing system at an automotive manufacturing plant. In south India. The objective of study was to improve export sales.
20. Palak p.seth et.al.; 2014[28]	Case study was carried out in an automotive industry in seat making process. After implementation of NVA reduced to a major value and also WIP reduced.
21. Maxwell Dzanya et.al.; 2015[30]	Applied VSM in glide manufacturing in Zimbabwe with the aim of eliminating waste and improving quality in production.
22. K.P.Paranitharan; 2015[35]	Carried out a case study based of VSM in Brass Lamp Manufacturing. A seven step methodology was used to eliminate NVA and for productivity improvement and to study the impact of VSM on industry.
23. S.R.vijaykumar et.al.; 2015[38]	Applied VSM with integration of KANBAN technique for aiming to achieve high quality products with maximizing productivity for selected one part family among product families.
24. Satish Tyagi et.al.; 2015[37]	VSM methodology successfully applied to current working processes, quality improvement, sustainable manufacturing. Applied VSM while product development is being carried out in their initial phase.
25. Martin et.al.; 2015	Demonstrated application of VSM on real case study and discussed its outcomes and to show that by using VSM organisation can achieve long and short term goals.

Table 1: Major Contribution in the field of VSM

III. PROBLEM DEFINITION

In this industry they were manufacturing Crusher Jaw plate. Jaw plate is a very critical component in working of crusher for stone cutting. This jaw plate manufacturing includes various operations from melting, moulding, knockout and degating, fettling, grinding etc. by applying VSM it was found that lead time and WIP were too high and processes contributing high value to L/T and WIP are identified. It was noticed that number workers could be reduced if operations been combined and optimized. He major processes steps were design making patterns making which were adding high C/T to processing L/T.

IV. METHODOLOGY

The methodology for implementation of value stream mapping is essentially having five steps. These all steps are to be performed in a sequential way. The sequence is as follows

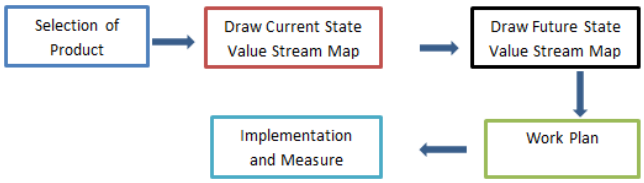

Fig. 1: VSM Methodology

A. Selection Of Critical Product Family

The first step is the selection of the product family from the product mix for study. This critical product family should be chosen after studying the product mix thoroughly. This product family will be the ground for further study.

B. Drawing Current State Value Stream Map

Data regarding the customer demand and company production should be collected in this step and data regarding processes and operations should be used to develop a current state map. This map will show the present scenario of the organisation. A wide range of the data related to supply and demand can be analysed by using current state map.

C. Drawing Future State Value Stream Map

After thoroughly analysis of CVSM, future state map will be developed depicting the various modifications and improvements incorporated in current manufacturing processes. FVSM shows ways to improve a process. After analysing the existing processes of an organisation, various proposals and suggestions for waste elimination and process optimization can give a way to the organisation for future improvements.

D. Work Plan

By using various lean tools, an organisation have to develop and select best and optimized implantation plan in order to achieve improvements in best acceptable ways. Some VSM symbols are used in VSM drawing for easy and comprehensive understanding. Some basic symbols are shown in fig 1.

E. Implementation and Comparison

This step shows the implementation of various suggestions made in FVSM. After implementation it becomes necessary to compare the outcomes with existing data. This shows us that how effectively the improvements are made and what the possible benefits could be.

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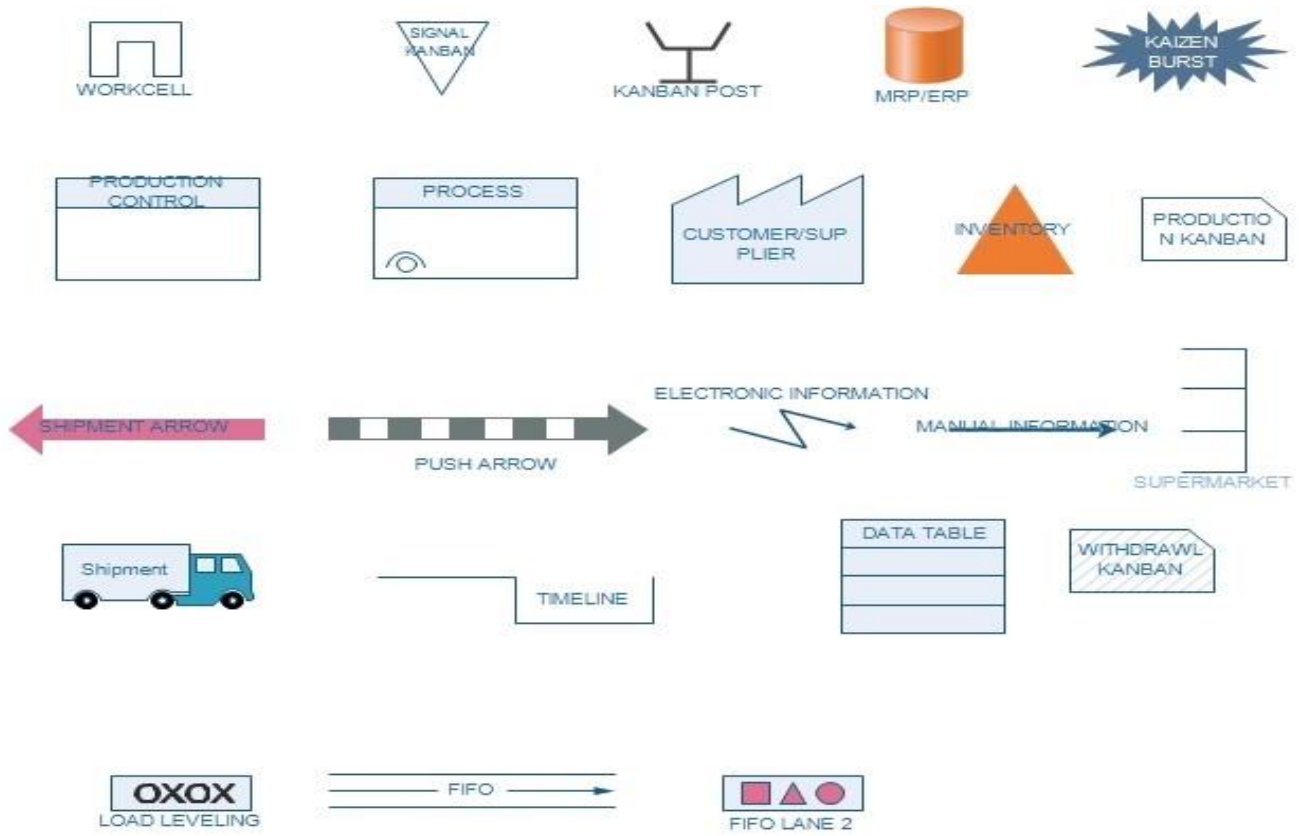

Fig. 2: VSM Symbols

V. CURRENT STATE VSM

The Current State Map also referred as Current Value Stream Map (CVSM) gives us information about what is currently going on in the organisation. it is a pictorial presentation of current data and information flow. Drawing with specialised symbols of VSM, current state map considers entire processes for targeted product or product family. Starting from the raw material procurement it ends with delivery of finished piece. Thus after developing CVSM for a targeted process, it becomes very easy to find out the factors and processes which are contributing in NVA and Waste production. It also gives indications to the areas which can be improved. Thus after data collection it is the very crucial step towards generation of future state map. Current state map for the product crusher Jaw plate is depicted on next page.

All the necessary data collected for CVSM was collected as per approach recommended by Rother and Shook (1999) with consulting managers, workers, shop floor supervisors and engineers. The first step towards development of CVSM is that the final product/ product family must be selected and sorted according to problem. This research paper is focusing on manufacturing of crusher jaw plate and the same product with associated manufacturing operations is selected for analysis.

After time study of various operations in manufacturing of the product the current state map developed is as shown in figure-

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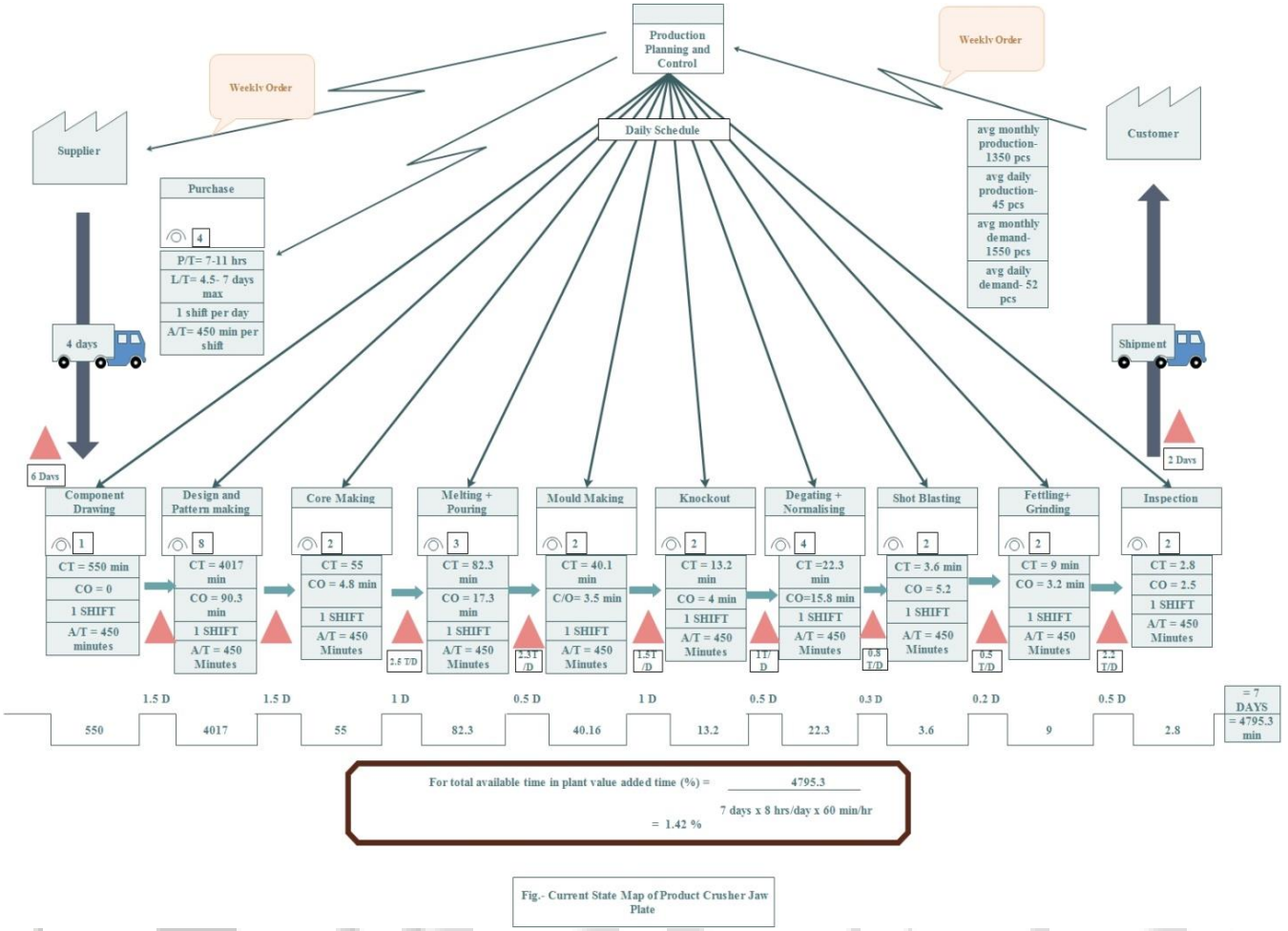

Fig.- Current State Map of Product Crusher Jaw Plate

Fig. 3: Crusher Jaw Plate- Current State Value Stream Map

Quantitative Analysis of Current State Value Stream Map-

After analysing the current state map thoroughly following data is found-

Total value added time = 4795.3 minutes

Total lead time to fulfil customer order = 7 days

For total available time in the plant value added time =

$$\frac{4795.3}{7 \text{ days} * 8 \text{ hours/day} * 60 \text{ min/hour}} = 1.42\%$$

Total number of operators(workers) working = 28

Total WIP = 10.8 Tonne/day

Total change over time = 146.6 Minutes.

The current state map was drawn with the help of information collected within the firm. With the information collected, a clear understanding of the entire manufacturing process is depicted for the product Crusher Jaw plate. Now areas associated with Non-Value added activities can be traced and waste identified so that avenues for improvement can be seen clearly and suggestions recommended accordingly for a leaner company. The next step after plotting CVSM is to identify non value added activities and to improve the processes by applying kaizen activities and other lean tools. The CVSM is developed keeping in mind the concept of Lean manufacturing. A few assumptions were made. These assumptions are that the demand is stable, machine utilization is 100% and shift timing is fixed. CVSM collects the information at the particular instance, so some variation in number of operators and production rate are not considered.

VI. FUTURE STATE MAP

The future state map is a visionary map drawn to propose suggestions and recommendations for an ideal value flow. Several lean manufacturing techniques are adopted to reduce lead time and increase throughput. With the aim of continuous improvement, this company is suggested several ways to reduce lead time, WIP, cut down the number of operators and to increase value added time percentage in available plant time. The suggestions includes use of supermarket concept to provide local storage, aid from external source, applying the concept of work cell, combining operations,5S,FIFO concept etc. these suggestions not only helps the company to improve its operation procedures but also opens new ways for future improvements.

After analysing CVSM improvement areas are identified using kaizen bursts which will lead to reduce WIP, L/T,C/T,C/O. a number of proposals are made to improve CVSM for this various modifications are done in the manufacturing processes of crusher jaw plate. To synchronise Takt time with C/T modifications in manufacturing steps are done i.e. combining operations,5S,Pull,FIFO etc. which are clearly shown in FVSM. Some activities should be eliminated which are not adding any value to the product. FVSM below shows areas that require improvements and ways in which they can be improved. After improvements lead time for the product

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manufacturing comes to 4.9 days from 7 days. The C/T is also reduced from 4795.3 minutes to 4262.2 minutes.

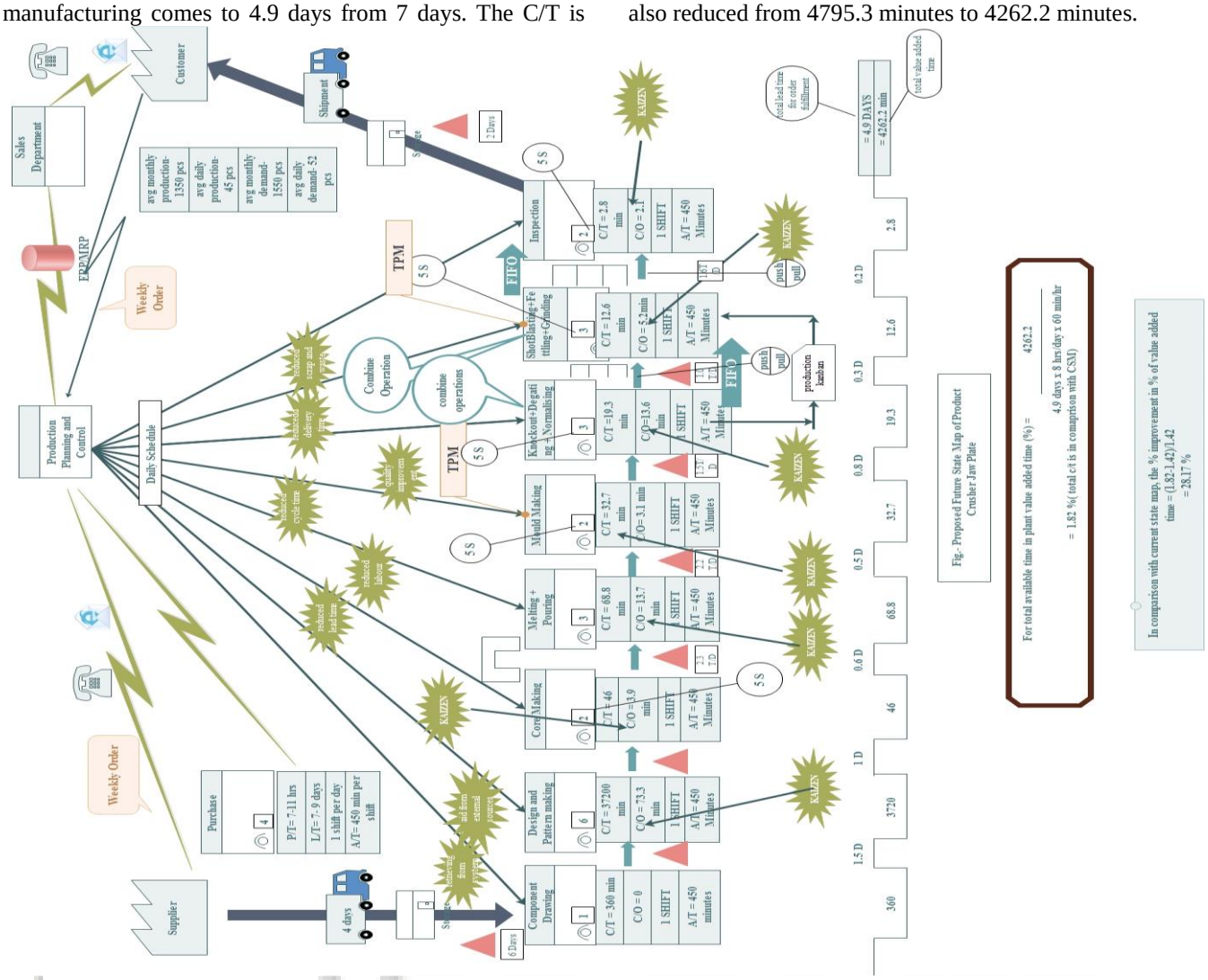

Fig. 4: Future Value Stream Map

A. Calculations

%value added time improvement = $\frac{(1.82-1.42)*100}{1.42}$ = 28.16%

Reduction in WIP = $\frac{(10.8 - 8.6)*100}{8.6}$ = 20.37%

Reduction in Lead Time = $\frac{(7-4.9)*100}{4.9}$ = 30%

Reduction in Cycle Time = $\frac{(4795.3-4262.2)*100}{4795.3}$ = 11.12%

Reduction in number of workers = $\frac{(28-22)*100}{28}$ = 21.43%

Reduction in changeover time = [(146.6-114.9)*100] / 146.6 = 21.62%

B. Improvement in Productivity

In current state the lead time was 7 days and after improvements suggested it becomes 4.9 days and it shows reduction in lead time by 2.1 days. This organisation produces about 45 pieces daily, then total amount produced- 2.1*45=94.5

This shows that earlier this company was producing 315 pieces in 7 days, now after improvements ability to produce in 7 days is 315+94.5=409.5 pieces (in 7 days). If we calculate for the whole month this amount is equal to 1755 pieces.

C. Comparison for Production in A Month

Current state production- 1350 pieces
Future state production- 1755 pieces
Increase in production- 405 pieces
% improvement in production- (405/1350)*100= 30%

D. Comparison for Productivity for A Month

	In Current State(CVSM)	In Future State(FVSM)
Productivity	1350 pieces	1755 pieces

Table 2:

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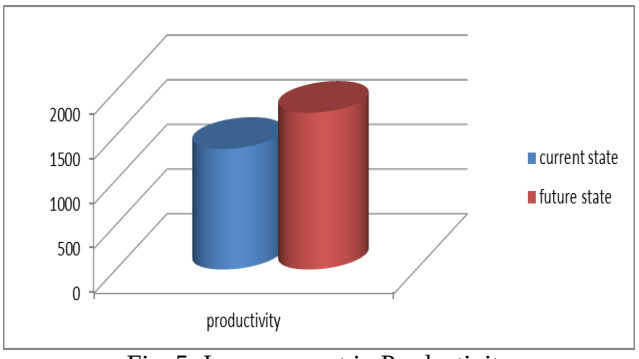

Fig. 5: Improvement in Productivity

VII. RESULT AND DISCUSSION

Every industry aims to maximize its productivity, profit and aims to minimize WIP,C/O,C/T,L/T, Waste and Rework etc. the common requirements of all these goals are the huge investment in capital and also proper tools to get these done. This research work has been intended to VSM, which is becoming an necessary tool for practising Lean manufacturing in actual production scenario. The results are shown in form of comparison between various process parameters for CVSM and FVSM.

Process parameters	Value in Current state	Value in Future state	% Improvement
% Value Added Time	1.42%	1.82%	28.16%
WIP(T/D)	10.8	8.6	20.37%
Lead Time(days)	7	4.9	30%
Total Cycle Time	4795.3 min	4262.2 min	11.12%
No. of Workers	28	22	21.43%
Change Over Time	146.6 min	114.9 min	21.62%
		Average Improvement	22.12%

Table 2: Comparison Between CVSM And FVSM

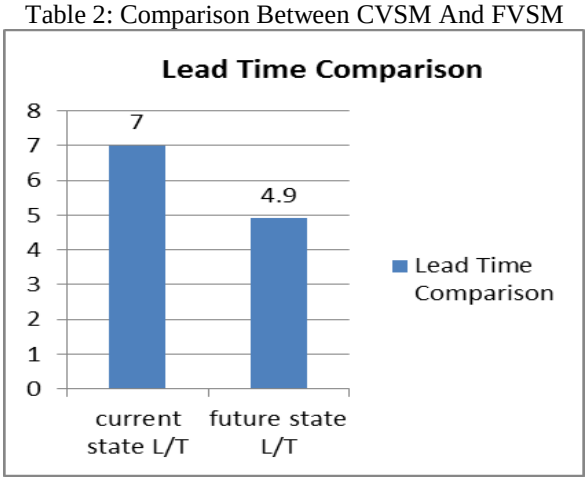

Fig. 6:

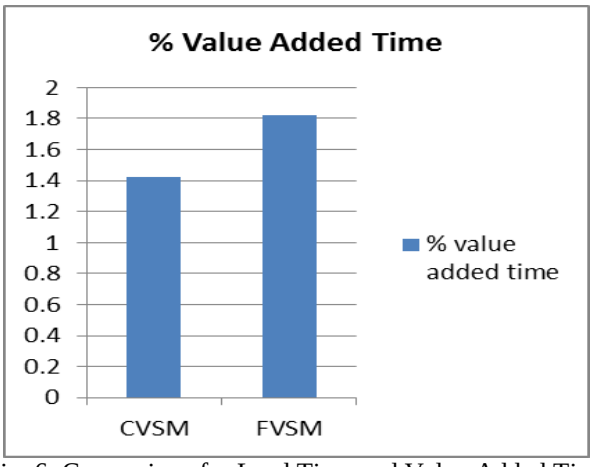

Fig. 6: Comparison for Lead Time and Value Added Time

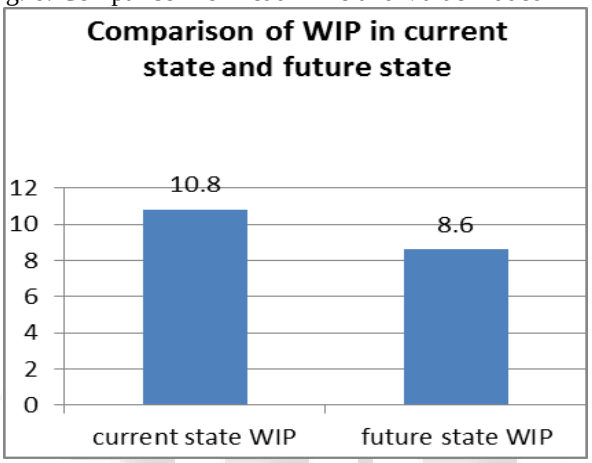

Fig. 7:

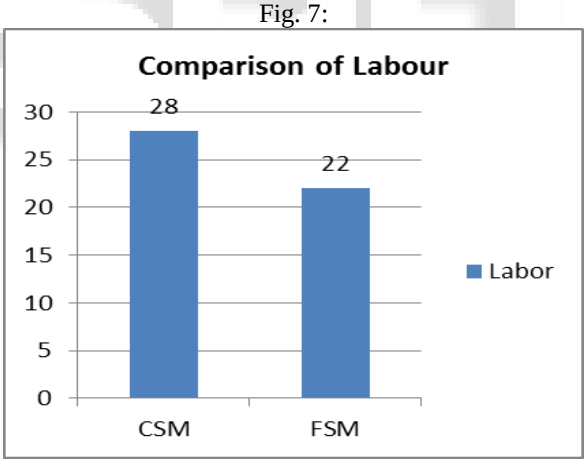

Fig. 8:

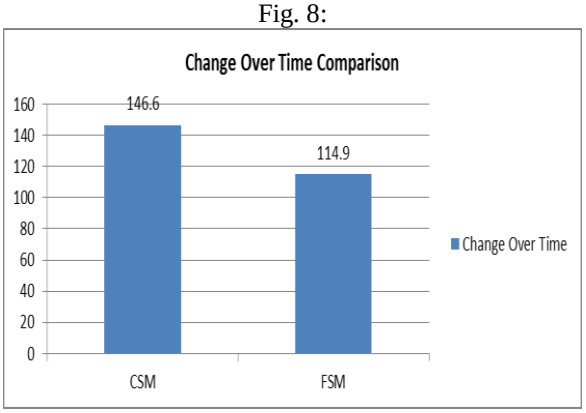

Fig. 7: Comparison For Wip, Labour And Changeover Time

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VIII. CONCLUSION

It is proven beyond doubt that VSM is a powerful tool for lean manufacturing and allows firms to understand and continuously improve its understanding towards lean. The present work provides a case study of improvement in productivity in a foundry industry by the application of VSM in the manufacturing of Crusher Jaw Plate. It focuses on the revamp of the operations by eliminating non value added activities and improving cycle efficiency through VSM. This paper compared the current state and future state of a manufacturing firm and witnessed 28.16% improvement in value added time, 30% reduction in lead time, 11.12% reduction in cycle time. On an average the overall improvement was found near to 22.12%.

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