Application Of Process Activity Mapping For Waste Reduction A Case Study In Foundry Industry

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Abstract: *Value Stream mapping technique involves flowcharting the steps, activities, material flows, communications, and other process elements that are involved with a process or transformation. In this respect, Value stream mapping helps an organization to identify the non-value-adding elements in a targeted process and brings a product or a group of products that use the same resources through the main flows, from raw material to the arms of customers. Process activity mapping is a Value stream mapping (VSM) tool has its origins in industrial engineering. The technique is known by a number of names although process analysis is the most common. Current effects of wastes on processes are observed. Process activity mapping steps are studied and wastes are identified. Different flow layouts are studied and best layout is selected that reduces the transport time. In this paper a case study in xyz foundry is carried out with current state map and future state map after following the different steps starting from the detailed time study of mapping process from raw material to final product. The steps including waste elimination techniques with conversion of existing waste into standard wastes are described. Statistical charts are prepared for the identification of bottleneck product is presented.*

Keywords: *Current State map, Future State Map, Process activity mapping, Value Stream Mapping, VSM tool, Waste Reduction.*

I. Introduction

Process is a series of actions, changes or functions that bring about an end result. (American Heritage, 1978).A Process is defined as one or more tasks that transform a set of inputs into a specified set of outputs (goods or services) for another person i.e. customer or process via a combination of people, procedures, and tools. (Wesner, Hiatt, Trimble, 1994) .The sequence of things [procedures] done to produce an output. A task is just one individual step in the process (Flanigann, Scott, 1995). Process mapping is the detailed mapping of the real process. Process maps: (a) Bring clarity to complex processes (b) Highlight non-value adding activities and (c) Start the process of thinking about improvements.

There are five stages to the process activity mapping [1]:

(1) The study of the flow of processes;

(2) The identification of waste;

(3) A consideration of whether the process can be rearranged in a more efficient sequence;

(4) A consideration of a better flow pattern, involving different flow layout or transport routing; and

(5) A consideration of whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed.

A case study in xyz foundry for waste reduction with process activity mapping is carried out to identify the process flow and non value adding activities. The study is focused only on foundry production line (Line 1 namely KOYO production line) which contributes to 98% of the castings of the foundry. The Value stream mapping tool is used to analyze both the flow of materials and the flow of information. The line is semi-automated and the casting goes through various processes drums, conveyors, sand separation, sand preparation, knock out, degating, shot blasting etc. Mapping the value stream activities of other products would give similar results with small differences in numerical values as some castings are simple, requires hot/cold box process while some are complex requiring cold/hot box process. However the bottleneck product Unterlage is selected for the study. This study is a case study applied for the foundry processes which are continuous processes as production lines are semi automated and the analysis uses the process activity mapping tool. This tool is selected with questionnaires, interviews and brainstorming sessions with manager and operators on the shop floor [2]. Marketing, production planning & control dept., pattern shop has helped us to give past record values of foundry production line for e.g. marketing dept. has given monthly customer order, production planning dept. has given the total foundry layout, pattern shop has given classification of simple and complicated jobs depending upon their work experience etc.

II. Case Study

2.1 Objectives

1. To use the Value Stream Mapping tool in identifying, quantifying and minimizing major wastes in a foundry production line.
2. To quantify by rank the seven wastes of lean within the foundry line.
3. To formulate practical means of reducing the identified major wastes.
4. The aim is to reduce lead time for process improvement.

2.2 Methodology

Step 1 Identify the bottleneck product for case study.
Unterlage 2884 and the product family is the bottleneck product corresponding to customer Wagner Trident (Fig.1).
Step 2 Causes for bottleneck
2.1 The product selected for the study is Unterlage corresponding to customer Wagner Trident as this product family possesses more casting weight up to 12.5kg which is greater than any product or product family on the production line. See fig.1showing the graph of customer versus average casting weights in kg.

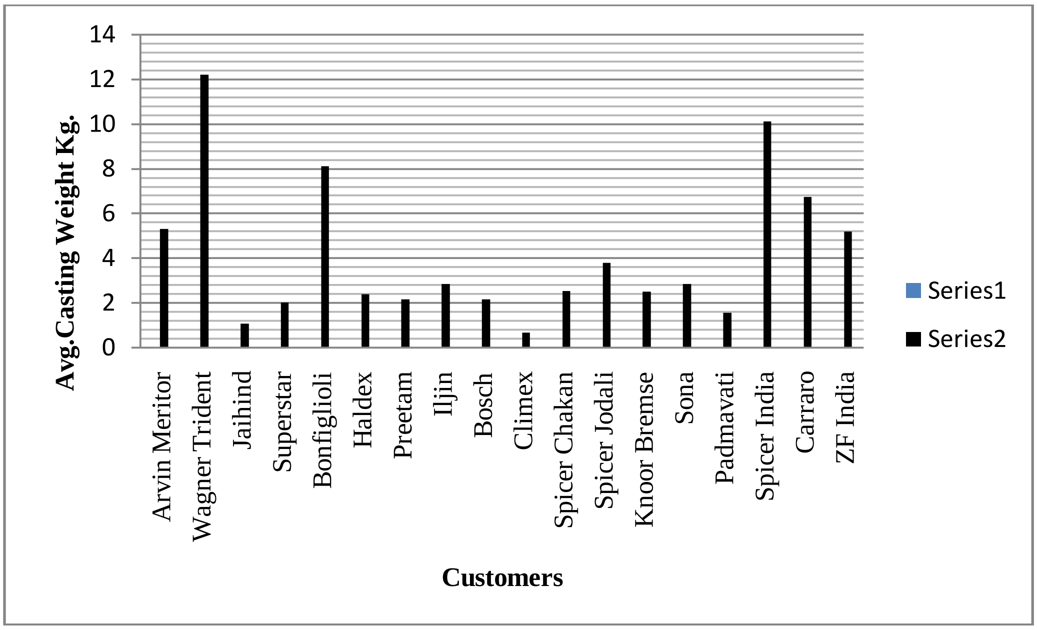


Fig.1 Bottleneck Product

2.2 Further the no. of cavities, pouring time and mould cycle times for Unterlage are greater than any other product or product family on production line1.

Step 3 Selection of the value stream mapping tool.

3.1 The Value Stream Analysis Tool (VALSAT) [1] is done to select the proper tool.

The value stream to be reviewed is first identified and through a series of preliminary interviews with managers the wastes are found out and ranked based on the weight age to a particular waste. The Value Stream analysis is done on the basis of correlation matrix of the seven wastes and the appropriate tools to use for analysis.

Table 1: The Seven Value Stream Mapping Tools [1]

Wastes / Structure	Mapping Tools						
	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure (a) Volume (b) Value
Overproduction	L	M		L	M	M	
Time Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate Processing	H		M	L		L	
Unnecessary Inventory	M	H	M		H	M	L
Unnecessary Motion	H	L					
Product Defects	L			H			
Overall Structure	**L**	**L**	**M**	**L**	**H**	**M**	**H**
Origin of Tool	Industrial Engineering	Time compression/ Logistics	Operations Management	New Tool	Systems Dynamics	Efficient Consumer Response / Logistics	New Tool
Notes: H = High correlation and usefulness M = Medium correlation and usefulness L = Low correlation and usefulness							

According to VALSAT [1] three tools namely Process activity mapping, Quality filter mapping and Production variety funnel have shown greater effectiveness to reduce the waste in foundry. However only Process activity mapping is considered for analysis in this paper for case study.

Step 4 Case details

The time study for all the foundry operations was carried out for 45 days by using stopwatch as a recording technique. The data is collected for the *bottleneck product per machine per shift per component.* The statistical bar charts are drawn to reveal the product details and analyze the problem.

Step 5 Study of the manufacturing process flow

The xyz foundry production line is semi automatic dedicated to flow the product. The process flow is shown in Fig. 2.The process starts from raw material along with component drawing, sand preparation step by step. The movement of material and information to produce final castings through various processes takes place from supplier to end customer.

Step 6 Identification of wastes

After the study of analysis the seven wastes are found in percentages as given in Table 2.

Table 2 Waste Identification

Sr. No	Type of Waste	Percentage
1	Overproduction	9.375%
2	Waiting	15.625%
3	Transport	15.625%
4	Inappropriate Processing	18.75%
5	Unnecessary Inventory	6.25%
6	Unnecessary Motion	9.375%
7	Defects	25%

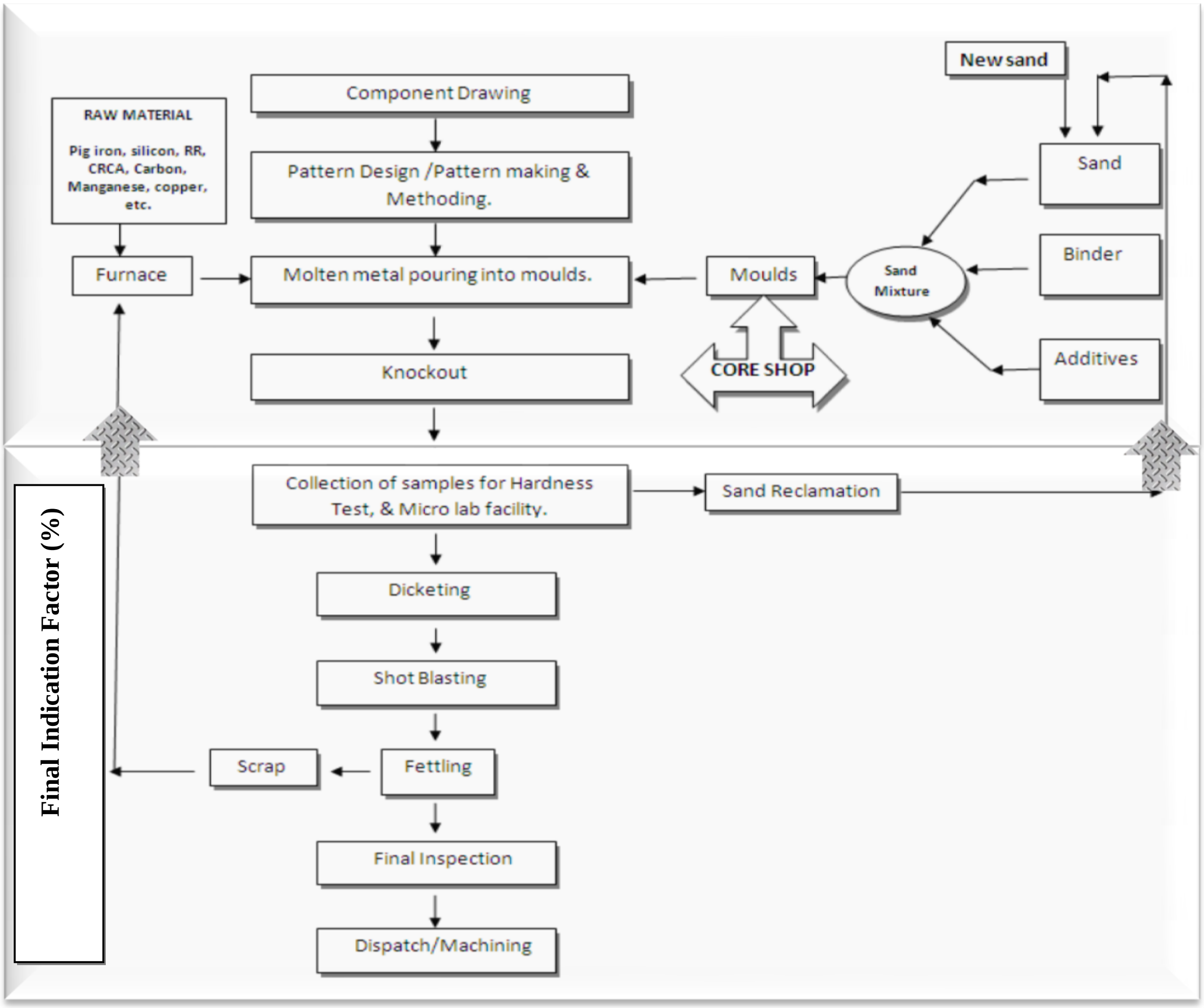
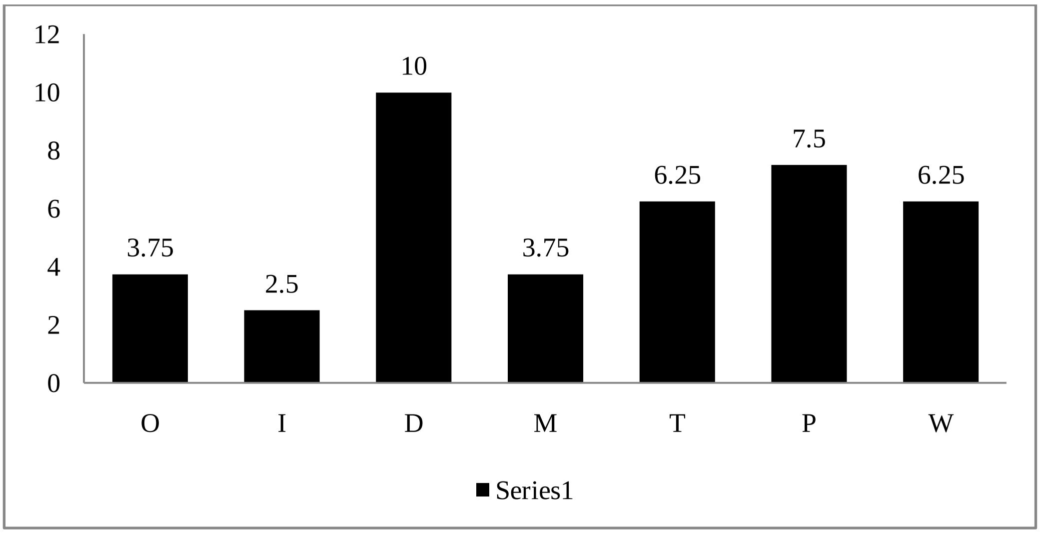


Fig.2 Process Flow of foundry



O=Overproduction, I=Inventory, D=Defects, M=motion, T=Transportation, P=Inappropriate Processing, W=Waiting
Fig.3Waste Ranking Bar Chart.

Step 7 waste ranking methods
Based on the VALSAT analysis and the time study analysis the waste ranking algorithm is employed and it shows the wastes that really need to be minimized as shown in fig.3.

Waste reduction is possible by using different lean techniques such as creating supermarket, Kaizen, JIT, FIFO etc. approach which can be conducted through discussions with shop floor employees.

Step 8 Identification of Value Stream
The value stream is identified and it comprises of all the activities that are Value added and Non Value added. Identification of value stream will give the detailed information about the product flow, wastes that occur within the value stream, step by step activities with cycle times, distances etc. It gives systematic procedure to tackle the improvement opportunities with lean techniques to satisfy the customer demand with increase in productivity.

Step 9 Mapping the Process Activities
Process activity mapping involving the preliminary analysis of the process [1] followed by the detailed recording of all the items required in each process is done for bottleneck product UNTERLAGE *per machine per shift per component* on KOYO automated line. As can be seen from this foundry example each step (1-38) has categorized in terms of variety of activity types (operation, transport, inspection and storage). The machine or area used for each of these activities is recorded, together with the distance moved, time taken and number of people involved. These are shown by darker red bold letters as shown in fig 4.
The total distance moved, time taken and people involved can be calculated and recorded [1]. The completed diagram (Figure 4) can then be used as the basis for further analysis and subsequent improvement. This is achieved through the use of techniques such as the 5W1H [1] (asking: *Why* does an activity occur? *Who* does it? On *which* machine? *Where? When?* and *How?*). The basis of this approach is therefore used to eliminate activities that are unnecessary, simplify others, combine yet others and seeks sequence changes that will reduce waste. Various contingent improvement approaches can be mapped similarly before the best approach is selected for implementation.

2.3 Current State Map
The time study is carried out by the stopwatch for 45 days on the shop floor of the foundry. We have gone through each and every process on the production line 1 by recording the travelling distances of men, materials, time taken by each activity, number of operators and workers right from raw material to final product dispatch. We observed raw material inventory, in-process and finished good inventory.WIP is more in between the degating-shot blasting-inspection-dispatch area. Layout was improper and due to that mixing up of parts, low productivity, poor housekeeping and unnecessary transportation of parts was there in fettling section.

Current state map is prepared keeping in view of the lean manufacturing principles. A few assumptions are also made for preparation of current state map. From past sales data at the industry under study, it is known that maximum demand of Unterlage 2884 may reach up to 3300 per month. The current state map captures information at a particular instance, which may vary from shift to shift. For the sake of analysis, the shift and operator-wise variation (which may be there) is not considered. Effective numbers of working days are 26 per month, number of shifts per day is three and working hours per shift are eight. Available working time per day is 86400 seconds. As per [3] Takt time can be calculated as

Takt time= {(Available working time per day (seconds)/customer demand per day (units)} = {(86400/ (3300/26)} = 681seconds.From current state map, value added time as a % of total time in plant = {(13497.54/ (15 Day X 24 hrs/day X 60 min/hr)} =0.62 %.

2.4 Future State Map
For future state map the following areas in which wastes like WIP, Inappropriate processing, bad layout etc. are identified and presented separately in corresponding process. After that the wastes are converted into standard wastes and techniques of waste elimination are described in latter part. First the processes in which the identified wastes exists are, a) Pattern Making, b) Core Making, c) Moulding, d) Shot Blasting, e) Fettling

Sr.No.	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
1	RAW MATERIAL	S	RESERV-OIR	-	-	-	O	T	I	**S**	D	PIG IRON,MANGANESE,COPPER ETC
2	COMPONENT DRAWING	O	DRAWN BY ENGINEER	-	1440	-	**O**	T	I	S	D	1 DAY FOR SIMPLE 3 DAY FOR COMPLICATED (1 SHIFT/DAY)
3	MOULD PATTERN DESIGN MAKING & METHODING	O	-	-	12000	1	**O**	T	I	S	D	COMPLICATED SINGLE PIECE PER PLATE (25 DAYS). FOR COPE & DRAG IT REQUIRES TOTAL 50 DAYS.(1 SHIFT/DAY)
4	CORE PATTERN MAKING	O	-	-	-	-	O	T	I	S	D	FOUNDRY OUTSOURCES CORE PATTERNS
5	RAW MATERIAL TRANSFER BY HOIST CRANE TO FURNACE	T	-	15.6	2	1+2	O	**T**	I	S	D	1 OPERATOR+ 2 WORKERS FROM STORAGE TO BASIN & BASIN TO FURNACE.
6	MELTING TIME	O	INDUCTI-ON FURNACE	-	30	-	**O**	T	I	S	D	
7	POURING INTO LADDLE	O	-	-	2	1+2	**O**	T	I	S	D	1OPERATOR + 2WORKERS

8	MOVING LADDLE FOR POURING UPTO TANDISH FLASK	T	-	16.5	4	1+2	O	**T**	I	S	D	TANDISH FLASK IS DESIGNED FOR POURING INTO MOULDS (1OPERATOR +2WORKERS)
9	MOULD SAND PREPARATI-ON(WAIT FOR MIX)	D	SAND MIXER TUMBLER	-	2	1+1	O	T	I	S	**D**	BINDER,ADDITIVES AND NEW SAND IS ADDED (1 OPERATOR+ 1WORKER)
Sr.No.	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
10	MOULD SAND TRANSFER BY CONVEYOR TO HIGH PRESSURE MOULDING LINE	T	-	21	0.3	-	O	**T**	I	S	D	
11	MOULD MAKING	O	HIGH PRESSURE MOLDING (KOYO)	-	0.25	2+1	**O**	T	I	S	D	NO. OF MOULDS=4(WITH CORE) AND=5(NON CORE)(2 OPERATOR+ 1 WORKER)

12	CORE SAND POURING TO CORE MAKING MACHINE	T	-	-	1	2	O	**T**	I	S	D	MANUAL POURING, RESIN BINDER SAND IS USED.
13	CORE SAND PREPARATION (WAIT FOR MIX)	D	SAND MIXER	-	0.25	-	O	T	I	S	**D**	SAND BOX TIME
14	CORE MAKING	O	CORE SHOOTER	-	1.5	1	**O**	T	I	S	D	SHOOTING PRESSURE 3-5 BAR (1 OPERATOR)
15	CORE HARDNESS TESTING	I	SCRATH HARDNESS TESTER	-	0.167	1	O	T	**I**	S	D	
16	POURING MOLTEN METAL FROM TANDISH TO MOLD	O	TANDISH FLASK	-	0.2	1	**O**	T	I	S	D	1 OPERATOR
17	POURED MOLD TO KNOCKOUT BY CONVEYOR	T	-	66	60	-	O	**T**	I	S	D	

18	KNOCK OUT	O	VIBRATOR	-	0.334	-	**O**	T	I	S	D	
Sr.No.	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
19	FROM KNOCK OUT TO HARDNESSTESTING BY TROLLYS	T	FORK LIFT	32	5	2	O	**T**	I	S	D	
20	HARDNESS TESTING FOR CASTING	I	BRINELL HARDNESS TESTER	-	120	1	O	T	**I**	S	D	REQUIRS ONE HOUR FOR COOLING AND ANOTHER FOR TESTING
21	FROM HARDNESS TO CUTTING	T	-	16	3	2	O	**T**	I	S	D	
22	CUTTING THE CASTING	O	CUTTING GRINDER	-	5	1	**O**	T	I	S	D	CUTTING FOR MICROSTRUCTURE TESTING.
23	FROM CUTTING TO MICRO TESTING	T	-	80	3	2	O	**T**	I	S	D	MANUAL TRANSPORT

24	MICROSTRUCTURE TESTING FOR CASTING	I	ELECTRON MICROSCOPE	-	30	3	O	T	**I**	S	D	INCLUDES POLISHING & TESTING
25	FROM KNOCKOUT TO DEGATING THROUGH DRUM & CONVEYOR	T	-	26.5	7	-	O	**T**	I	S	D	
26	DEGATING	O	ONLINE WEDGE CUTTER	-	0.17	1+1	**O**	T	I	S	D	RUNNER,RISER SEPARATION FROM CASTING (1OPERATOR+1 WORKER)
Sr.No.	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
27	FROM DEGATING TO SHOT BLASTING BY CONVEYOR	T	-	9.1	3	-	O	**T**	I	S	D	
28	SHOT BLASTING	O	SHOT BLASTING MACHINE	-	5	-	**O**	T	I	S	D	

29	FROM SHOT BLASTING TO FETTLING BY CONVEYOR	T	-	19	3	1	O	**T**	I	S	D	INCLUDES ONLINE PRIMARY INSPECTION (1 INSPECTOR)
30	FETTLING & POINT GRINDING	O	GRINDER	-	15	1+1	**O**	T	I	S	D	POINT GRINDER AND GRINDING WHEEL (1 OPERATOR+ 1 WORKER)
31	FROM FETTLING TO FINAL INSPECTION	T	MANUAL TRANFER	4	0.5	1	O	**T**	I	S	D	
32	FINAL INSPECTION	I	-	-	3	1	O	T	**I**	S	D	MANUAL INSPECTION (1 INSPECTOR)
33	OIL DIP	O	OIL TUB	-	0.083	1+1	**O**	T	I	S	D	CARRIED OUT TO PREVENT RUSTING (1 OPERATOR)
34	AWAIT TRUCK	D	-	-	60	-	O	T	I	S	**D**	
35	AWAIT FILLING THE TROLLEY	D	-	-	2	2	O	T	I	S	**D**	

36	FROM TROLLY TO TRUCK BY FORK LIFT	T	-	85	3	1	O	T	I	S	D	
Sr.No.	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
37	WAIT TO FILL FULL LOAD	D	LORRY	-	60	2	O	T	I	S	D	FILLING LOAD AS PER CUSTOMER ORDER
38	AWAIT SHIPMENT	D	LORRY	-	420	1	O	T	I	S	D	DISPATCH
	TOTAL		38 STEPS	**390.7**	**14291.754**	**47**	**14**	**13**	**4**	**1**	**6**	
	OPERATORS				**13497.537**	**13**						
	% VALUE ADDING				**94.44 %**	**27.66%**						

Fig.4 Process Activity Mapping

Identification of Wastes in the above foundry processes:

I) Pattern Making

1. Patterns must be finished, edges, burrs should be removed.

II) Core making

1. Three cavity core boxes for component 1 were not enough to complete production requirement.
2. Core Box of 2 cavities & core for component 2 was solid creating gasses problem in castings and not enough to complete production requirement.
3. One cavity core box for component 3was not enough to complete the production requirement.
4. Core weight is more for Slip Yoke 1180 which is 0.370 kg.

III) Moulding

1. Spillover of dust in turn affecting the environment in mould sand plant.
2. Moulding sand hopper was damaged so that sand leakage was more in the mould making section.

IV) Shot Blasting

1. Due to m/c breakdown of 3-4 days WIP is more in this section.

V) Fettling

1. Mixing up of different parts due to bad layout.
2. Poor housekeeping leads to low productivity.
3. High transportation of parts.

Classification of wastes into standard forms and techniques of elimination adopted:-

Table.3 Techniques of wastes elimination.

Operations	Waste	Type	Technique of Elimination
Pattern Making	1.Patterns must be finished, edges, burrs should be removed	Inappropriate Processing	Abrasive grinding brush introduced.
Core Making	1.Three cavity core boxes for component 1 were not enough	Machine Error	Design and Process Review.10 Cavity Core Box is made.
Operations	Waste	Type	Technique of Elimination
	2. Two cavity core box for component 2 was solid creating gasses problem in castings.	Machine Error	Design and Process Review.6 Cavity Core Box is made.
	3. One cavity core box for component 3 was not enough.	Machine Error	Design and Process Review.2 Cavity Core Box is made.
Moulding	1. Spillover of dust in environment.	Machine Error	Design and Process Review. Containers were provided for collecting the dust.
	2. Moulding sand hopper was damaged causing sand leakage.	Machine Error	Design and Process Review. Hopper welding with proper direction was done.
Shot Blasting	1. M/c breakdown caused more WIP.	Waiting	Total productive Maintenance (TPM) or Preventive Maintenance.
Fettling	1. Mix up of different parts due to poor layout.	Waiting	Part Specific self concept was adopted.5S was used.
	2. Low productivity due to bad poor housekeeping.	Waiting	Part Specific self, 5S was used.
	3. High transportation of parts	Transportation	Cellular Manufacturing or Group technology.

From future state map, value added time as a % of total time in plant = {(13497.54/ (11 Day X 24 hrs/day X 60 min/hr)} =0.85 %.The future state map indicates average 23% waste reduction in the critical areas of unnecessary inventory, transportation and waiting.

The concept of supermarket came into picture to reduce the in process inventory or WIP. A ‘‘supermarket’’ is nothing but a buffer or storage area located at the end of the production process for products that are ready to be shipped (Rother and Shook, 1999). On the other hand, producing directly to shipping means that only the units that are ready to be shipped are produced. Currently xyz foundry produces all the automotive Spheroidal Graphite Iron products (S.G Iron) and sends them to a holding area where they are stored with other products waiting to be shipped. However, this is done based on a push system, and components can wait a long time in this area before being shipped. The introduction of supermarkets is necessary only at the finishing end where large amounts of inventory exist between different workstations. In addition to the shipping supermarket recommended after final inspection, three additional supermarkets are needed to create a continuous flow. One before the Shot blasting, one before the fettling process and one before final inspection as flow displayed in Fig. 6. First in between degating and shot blasting ,2nd in between shot blasting and fettling,3rd in between fettling and inspection & 4th after the final inspection before the dispatch. Instead of Kanban pull, manual push system is employed to fill the supermarket to their required capacity. Kaizen continuous improvement programmes were carried out at pattern making, core making, mould making and fettling departments with Total Productive Maintenance (TPM) and 5s as explained above in table 3. First In First out (FIFO) concept was employed before degating, shot blasting and fettling.

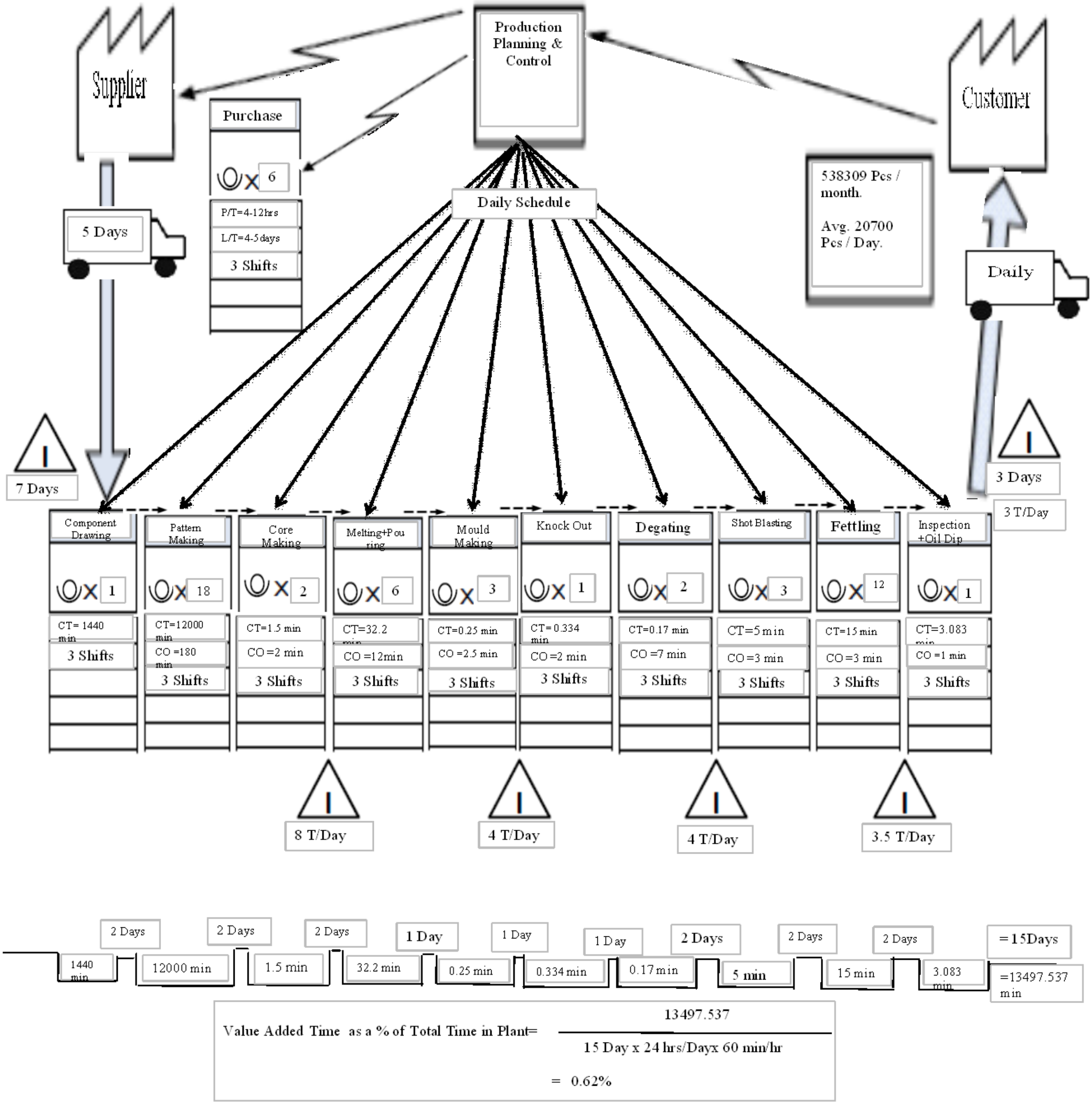


Fig 5.Current State Map

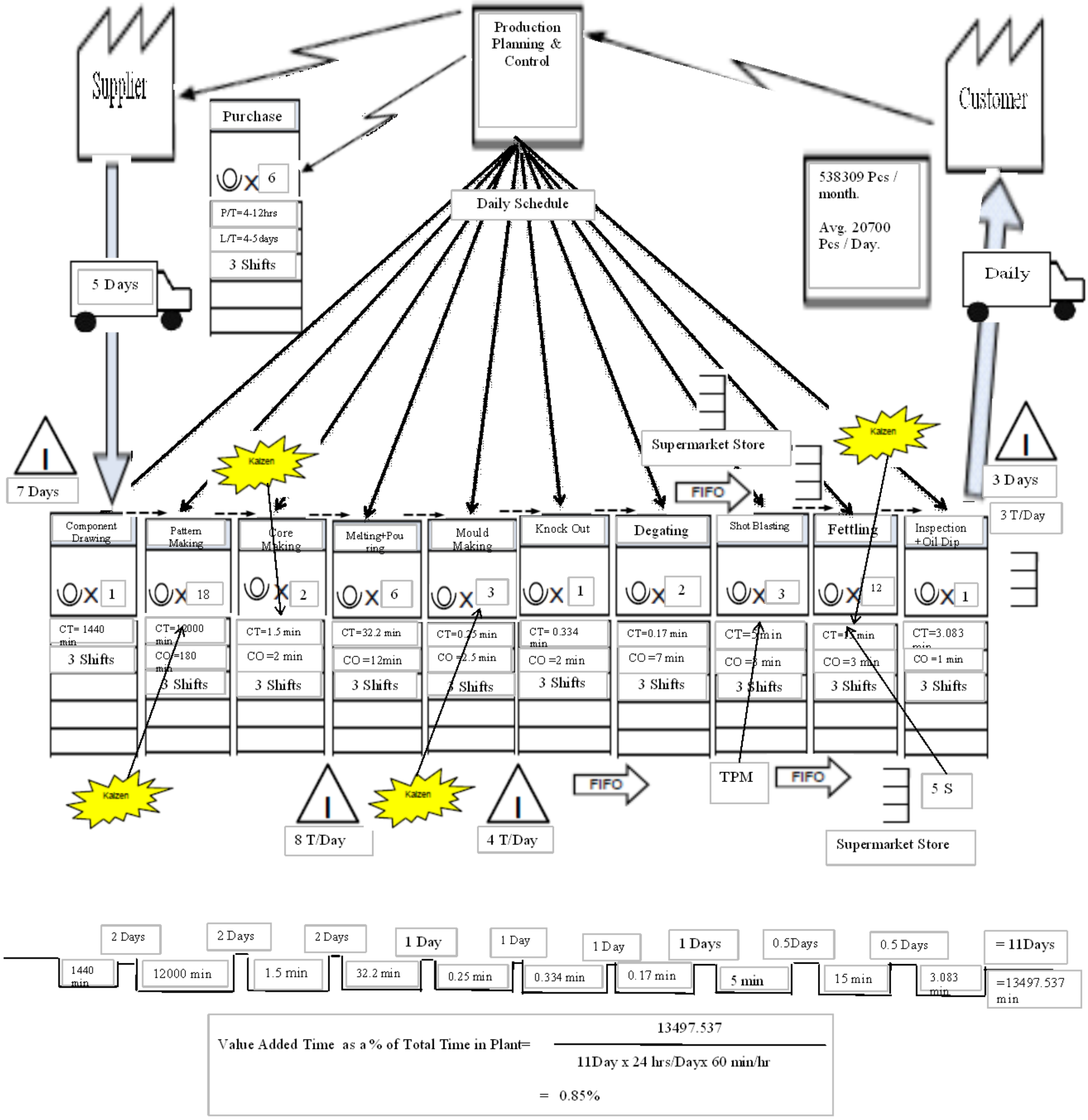


Fig 6. Future State Map

III. Conclusion

Value stream mapping tool can be used effectively in any kind of sectors as it is a world class manufacturing tool. The analysed study is case study in foundry industry. The prime objective is to carry out Process Activity Mapping for waste reduction. In this study bottleneck product was identified. Further Value Stream Analysis Tool (VALSAT) was employed for identification of wastes in a process. The significance of each type of error was studied and waste ranking was carried out. Current state map is plotted to assess current status. Waste elimination techniques are presented and future state map is also preferred for improvement. The results of study shows 23% waste reduction in the areas of unnecessary inventory, transportation and waiting. It is however to be noted that there is a significant cost to complete any required changes but the increased throughput against takt time will pay back for investment.

The authors are currently working on this project in a foundry situated in Maharashtra (India).This study is carried out on foundry production Line 1(KOYO),which produces 98% of total castings in foundry, therefore study is focused on 1st production line. A similar analysis on other production line 2(DISA) may show similar trend of results. Heavy complex castings are produced on second line contributing to only 2% of total castings. Besides authors are also working on Production Variety Funnel and Quality Filter mapping tools for process improvements. Value stream mapping tools can be effectively employed to reduce wastes and to improve the process.

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