Management Science Letters 13 (2023) 51–64

Contents lists available at GrowingScience

Management Science Letters

homepage: www.GrowingScience.com/msl

Productivity improvement using different lean approaches in small and medium enterprises (SMEs)

Amrit Kumar Das[a] and Manik Chandra Das[b*]

[a]*Department of Industrial Engineering and Management, Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata, Nadia-721249, India*
[b]*Department of Industrial Engineering and Management, Maulana Abul Kalam Azad University of Technology, Haringhata, Nadia-721249, India*

C H R O N I C L E

Article history:
Received: August 3, 2022
Received in revised format: August 20 2022
Accepted: September 2, 2022
Available online: September 6, 2022

Keywords:
SMEs
Lead time
LMT
VSM
TAKT time
Productivity

A B S T R A C T

Small and Medium Enterprises (SMEs) play a crucial role in the Indian economy. To remain competitive in the global market, application of Lean Manufacturing Techniques (LMT) helps SMEs to improve their processes in alignment with customer needs. The purpose of this study is to reduce overall lead time by identification and eliminating non-value added activities (NVA) from the manufacturing system. In this paper, the current manufacturing processes have been thoroughly studied using the principle of work study. Several lean approaches such as- TAKT time computation, Value stream Mapping (VSM), layout optimization, Kanban, Andon etc. have been used to make improvement in line efficiency and hence productivity. The study shows that use of line balancing technique, matches the cycle time with calculated TAKT time. And the efficiency of the line has increased approx 10% and hence balance delay got reduced. Again VSM helps to reduce the lead time of foundry shops by 51 minutes. It is one of the few studies that deal with productivity improvement in Indian SME.

1. Introduction

The term "Lean" refers to a distinct method of thinking that comprises a collection of procedures and operational principles for identifying and eliminating waste in pursuit of the most efficient method (Van Der Wiele et al., 2006). The focus of this concept is to improve processes efficiency with reduction of specific costs. So, it can be said that lean thinking is a methodology to organize the system in such a way that there should be no waste during the process (Jeffery, 2004). As waste is inversely proportional to the quality of the process, therefore, the main goal of lean is to eliminate non value adding items from the system so that it can save resources, reduce processing time, and minimizes production cost thereby improving productivity with quality. During the last three decades, lean manufacturing has been widely used in industry to identify wastes and create proposals to reduce the same. Many large organizations in India have successfully adopted lean manufacturing, but SMEs have yet to do so to reap the benefits. SMEs are the backbone of the Indian economy, and lean implementation can help them stay afloat in today's market by fulfilling customers' requirements with minimum lead time and at economical price.

The objective of this paper is to implement various lean approaches in a medium enterprise to improve the current level of productivity through improvement of lead time, cycle time and line efficiency. After finding out the root cause for not meeting customers' demand, VSM is used to find the Non-Value Added (NVA) time in the process flow. It has been observed during

* Corresponding author.

E-mail address: cd_manik@rediffmail.com (M. C. Das)

doi: 10.5267/j.msl.2022.9.002

study that the processing of the critical item takes longer than the TAKT time for which meeting customers' demand gets delayed resulting in reduced market share of the enterprise. In this context, lean manufacturing tools have been applied systematically to reduce the lead time of the process by eliminating NVA.

This paper is organized as follows: Section 2 reviews relevant literature in the field of study. Section 3 describes the methodology. A case study has been presented in section 4. Section 5 deals with application of the lean manufacturing techniques. Results and discussion have been described in section 6. Conclusion is given in the last section.

2. Literature Review

"The Machine that Change the World" by Womack et al. (2007) was the first book to present the lean principles. As the author wrote by observing the manufacturing system at Toyota, so it is called that Lean is the subset of Toyota Production system (Ohno & Bodek, 2019). From then many studies were continuing dealing with lean and its implementation on manufacturing sector. But there has been a rising focus in both manufacturing and service firms over the last three decades on adoption and development of improvement approaches to reduce costs and boost the advantages (MĺKva et al., 2016). According to Confederation of Indian Industry (CII) SMEs play a vital role for Indian economy as it contributes approximately 30% of Indian GDP (https://www.cii.in/). So recent trends include the implementation of lean techniques and its concepts on SME sector for increasing productivity by reducing 7 types of wastes (Shigeo, 1989) as defined by Toyota Production System. For this present work new concepts and ideas have been collected from literatures published in various national and international research journals of repute. An effort has been put to see how Indian SMEs and other multinationals are exploring lean manufacturing techniques to improve productivity.

2.1 Researches carried out in National level

Kumar et al. (2018) focused on reducing the machine set up time and cycle time for friction welding process for earthmoving vehicles. Their study mainly considered on two major components which were cylinder rod and rod eye, friction welded together. Using VSM and time study method they changed the layout and succeeded to reduce the set up time. After implementing of lean methods, they showed that productivity increased up to 50%. They also concluded that total cost saving of INR 53,700 could be achieved per year. Kumar et al. (2014) pointed out that VSM with Lean-Kaizen tool as fruitful to reduce all kind of inefficiencies in any organizations. They advocated that all kinds of products and process could be improved by using this method simply. In an article Kumar and Kumar (2014) studied the existing operation time and line balancing for a truck body assembly plant to overcome the station delay. After implementing lean tools like standardize work approach, VSM and line balancing they found that cycle time reduced to 37.5 min from 90 min and line efficiency increased to 30.09% from 17.5%. Nallusamy (2021) took single phase submerged pump from a different kind of water pump manufacturing Industry of Chennai for his study. The industry was facing a problem of large number of work in progress (WIP) inventory and high moving time from a workstation to another. He had mainly tried to eliminate the non-value added activities which were wastes to minimize the lead time through VSM method. He introduced line balancing, layout optimization, Pareto chart and cause and effect diagram to figure out the result and concluded that the efficiency increased up to 97% and the total lead time was cut by around 13%. As demonstrated by Nallusamy (2016) the primary goal was to look at the line balancing tool that was used in CNC machining chambers to balance the workload among the workers and increase employee utilization. After implementing lean tools like work standardization, time study, VSM and Line balancing, non value added (NVA) activities were identified and eliminated resulting 17% reduction of NVA activities. Productivity increased from 5 to 7 components per day. Nallusamy and Ahamed (2017) tried to find out the opportunity to reduce the number of action drastically and simplify the process. As a result they used VSM method to identify value and non-value added activities. Using lean tools like 5S, VSM and line balancing, they successfully reduced the cycle time by 40%. After applying the lean tools the NVA activity time reduced about 15% and cycle efficiency increased to 81.18% from 71.24%. Nallusamy and Saravanan (2016) worked on reducing the lead time without changing the existing working system in a small scale automotive component manufacturing Industry. It was observed that by using lean tool the cycle time reduced to 350 seconds from 1500 seconds. The overall lead time decreased to 3946 seconds to 5780 seconds by introducing standard operating procedure. Pandit et al. (2014) examined that the case company was having difficulty for fulfilling the demand from their customer. When the historical data was examined, limits were discovered on two machines in the production line that needed to be focused. The approach to cope with the increased demand was to eliminate bottlenecks on these resources, as well as to reduce raw material and work-in-process inventory. After implementing line balancing concept they successfully increased on time delivery by 15%, production volume by 17%, hence profit increased 17% and work in progress inventory reduced by 83%. Prashar (2014) found that lean-kaizen had been a comparatively modern lean technique but was unknown to ground level worker in most of the Indian organizations including the higher authority of the organization. Lean-Kaizen was a simple but prime improvement technique that could help to eliminate different inefficiencies in the organizations. Rao et al. (2017) studied a dairy industry aiming to fulfill the market demand developing a production line capacity to produce 12 milk homogenizer machines per month while the actual production was 10. They used various lean tools like 5S, VSM, Line balancing and kaizen. Saraswat et al. (2015) followed the process and cycle time of a bearing manufacturing industry. Using VSM they found that annealing process and CNC Machining processing had higher cycle time and work in process. After implementing lean principles and techniques the lead time was reduced from 7.3 days to 3.8 days. Production lead time had shortened down to 409 seconds to 344 seconds, also at each work station WIP had been reduced. The researchers Rekha et al. (2016) studied a passenger seat production company located in Chennai. They found that the problem occurred in assembly section with its irregular and unbalanced cycle time. Hence they implemented lean methods to find the NVA activities and increased the productivity. As a result total cycle time reduced to 26.28%, productivity increased up to 14%. Upadhye et al. (2010) examined micro small and medium enterprises' (MSMEs) challenges and demonstrated a case study to show how lean manufacturing system (LMS) improved a mid-sized auto component manufacturing plant in India. They applied different lean tools in different parts of a particular north Indian company. They showed that machine set up time, cycle time and rejection rate had been reduced resulting an increase in machine availability and current capacity after implementing LMS. Venkataraman et al. (2014) focused in a Crank-shaft manufacturing industry on reducing cycle time and capital investment by using VSM and Kaizen tool. They found out different types of wastes such as unnecessary inventory, excess scrap, extra time for processing, additional manpower and additional cycle time. They successfully reduced the cycle time and capital investment after implementing VSM and Kaizen tool. Vinodh et al. (2010) described a research project that took place in an Indian camshaft manufacturing company. After making the necessary observations and computations, the current state map was created. To achieve the target, strategies such as 5S, Poka-Yoke, and others were adopted and improvement noticed in cycle time, idle time, WIP inventory and the defective scrap. So on time delivery got increased up to 85%. By implementing VSM, Singh et al. (2011) reduced work in progress inventory by 80.09%, finished goods inventory by 50%, lead time of product by 82.12%, cycle time 3.75% and required manpower by 16.66% in an Indian small manufacturing company.

2.2 Researches carried out in International level

Álvarez et al. (2009) pointed out the analysis and the application of VSM to get better result by means of Kanban and Milkrun method. The outcomes had been measured by two lean metrics viz. lean rate and dock to dock. The result indicated that the inventories followed by idle time got reduced. Pintu Junior and Mendes (2017) worked on an electronics part manufacturing company to reduce the water and energy consumption using various lean tools like 5S, Kaizen, PDCA cycle, Poka-Yoke and standardize work. They became successful to reduce the cost by reducing water and energy consumption. Azizi (2015) worked in an electronic tag manufacturing company. Use of VSM and Kaizen method helped to minimize the machine setup time and to remove other non value-added activities. Dewi et al. (2021) studied a production company that often delayed to fulfill the customer demand, also a produced defective products. They observed that non value added activities consumed 59.8% time. They proposed lean methodology and some of its techniques that improved inspection process, daily maintenance, standard operation procedure etc. to reduce set up time and to minimize non value added activities. Dotoli et al. (2011) proposed a framework to find out the critical concern about processes and evaluating them in order to select the most appropriate needs for achieving the desired improvement. They used VSM integrated analytic hierarchy process (AHP) for the purpose. MÍkva et al. (2016) examined management standard and operational standard for continuous improvement of any organization. With the help of Kaizen, 5S techniques and PDCA cycle they formed a baseline. Oliveira et al. (2017) used VSM method to find out wastes and applied total productive maintenane (TPM) to achieve better quality, higher productivity, reduce breakdown for mechanical equipment of a manufacturing company. They also discussed the benefits of other methods like standard work, 5S, Visual Management, Kanban, line balancing. Rahani and Al-Ashraf (2012) set their goal to enhance the production and shorten the lead time by finding out the root cause of hidden wastes and by eliminating them. Rossit et al. (2019) presented a framework for supporting late customization strategies in assembly line systems. The ability of putting this concept on an autonomous system was presented as an innovation in this framework. At the same time, it offered the flexibility of re se-quencing the workflow if necessary, increasing the likelihood of late changes being included. Sabaghi et al. (2015) proposed a model to calculate basic performance measures and analyzed the system to reduce the performance lead time and work in progress inventory. Three methods namely kanban, TPM and set up time reduction were applied for the purpose. A simulation model was run to investigate the basic performance measures, as well as assessing the system settings. Salwin et al. (2021) explained the application of VSM in the manufacture of steel pipes. Their purpose was to present the VSM method as part of the analysis and process improvement. It was observed that productivity improved by 17% and wastes reduced by 1.7 times as compared to current state of production. Santosa and Sugarindra (2018) removed motion and waiting type wastes from the system by implementing kaizen tool. Also they shortened the cycle time to 41.90 min from 51.16 min and improved WIP inventory using VSM tool. They concluded that lead time reduced to 0.167 days, earlier which was 0.222 days. The findings supported the assumption that both techniques are broadly applicable, implying that higher levels of Industry 4.0 adoption might be easier to attain with the implementation of LP practices in the firm.

3. Methodology

Identified goals help to frame and determine research methodology for this present work. During the manufacturing process of the product, all activities carried out in workstations including assembly activities of the components, the flow sequence has been thoroughly investigated. The study begins with the observation at shop floor. Fig. 1 illustrates the flow chart of the proposed method. To find out the root cause of not meeting delivery target, 5'S why tool has been applied. The Five whys (or 5 whys) is a repetitive interrogative method for determining the cause-and-effect relationship at the root of a problem. The main focus of this method is to uncover the hidden route cause of a defect or problem by asking "Why" again and again. Each response acts like base for the next question.

1. Process Study
2. Problem Identification
3. Finding root cause of Waste using 5's Why tools
4. Time and Motion study, Existing task time and precedence diagram
5. Existing VSM, Line Balancing calculation
6. Implement Kanban and Andon conocepts to minimize NVA time
7. Proposed state of VSM and Data collection
8. Proposed line balancing
9. Layout optimization
10. Result and Conclusions

Fig. 1. Flow chart of the proposed method

The necessary data are collected to make the present state of VSM and to identify opportunities for change. VSM aids in the depiction of a material flow as well as the flow of information that is returned during production (Forno et al., 2014). This VSM is utilized to identify value added (VA) activities in the manufacturing process as well as to help eliminate NVA activities. This mapping is the most crucial tool for finalizing and pinpointing the opportunities for various team tactics.

The existing VSM has been utilized to draw the flow of material starting from raw material to the finished product to calculate the TAKT time (Eq. 1).

$$\text{TAKT time}=\frac{\text{Total available time/day}}{\text{Demand/day}} \tag{1}$$

In the next step, time and motion study and line balancing technique have been employed to determine line efficiency and balance delay, as given in Eq. (2-3).

$$\text{Line Efficiency}=\frac{\text{Total performance time}}{\text{Total available time}} \tag{2}$$

$$\text{Balance Delay}=1-\frac{\text{Total performance time}}{\text{Total availabe time}}=(1-\text{Line Efficiency}) \tag{3}$$

Subsequently, layout optimization has been made to minimize the transportation wastes. Further, Andon and Kanban methods have been used to reduce the unnecessary movement and waiting wastes. Andon is a lean tool that controls and notifies instant necessary information and signals visually. Kanban is also an important lean tool. In Japanese it means “Signboard or billboard”. Kanban tool helps to manage the production flow as well as the material flow. It was applied by Toyota for pull production.

4. Illustrative Example

A case study has been conducted in an Indian medium enterprise which produces railway items. One such item is CASNUB 22 which is a type of rail bogie the enterprise produces. There are many types of CASNUB bogie (Birhade, 2016) like CASNUB-22W, CASNUB-22W(M), CASNUB-22NL, CASNUB-22NLB, CASNUB-22HS etc. The company manufactures all types of CASNUB bogies according to the requirements of the customer. The main components of CASNUB bogie includes side frame and bolster are manufactured inside the company and the additional parts like spring, pivot top, pivot bottom and other accessories are imported from ancillaries to assemble the whole product. Fig. 2 provides a glimpse of the final product.

Fig. 2. CASNUB- 22W bogie

4.1 Brief description of the product and manufacturing process

Two cast steel side frames and a floating bolster constitute the main structural form of CASNUB 22 bogie. Bolster is a bogie component that forms part of the bogie and car body interface. Bolster is resting on the boogie secondary suspension. Car body also has a similar component that links to the bolster of the bogie. Side frame design looks like a box section. The primary suspension supports the frame on the axle boxes, allowing for radial wheel set adjustability (Bharadwaj, 2017).The company produces these bolster and side frames and assembles them with coil spring, pivot top and pivot bottom. One bolster and two side frames are needed to make one CASNUB bogie with the load bearing coil spring and center pivot top and bottom. Whole assembly of the product has been shown in Fig. 2, and 2D drawing of the bolster and side frame has shown in Fig. 3.

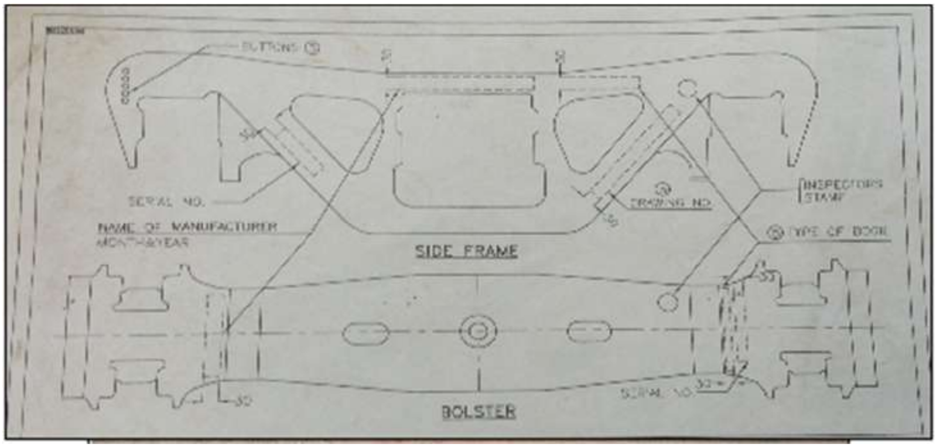


Fig. 3. 2D drawing of side frame and Bolster

The existing layout of the shop floor has been shown in Fig. 4. There are six numbers of divisions in the shop floor which are foundry shop, melting shop, fettling shop, machining shop, heat treatment and assembly shop.

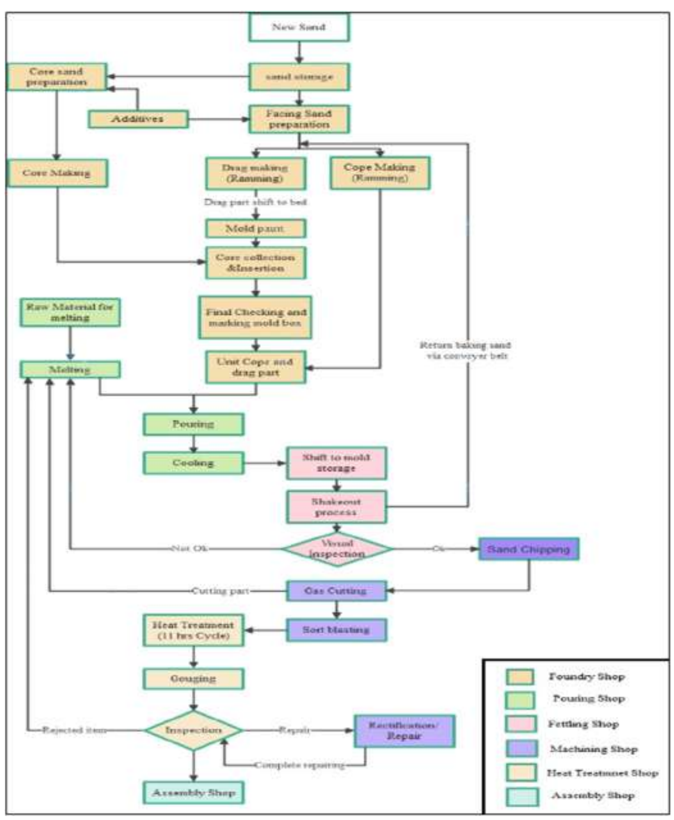


Fig. 4. Existing layout of shop floor

4.2 Application of lean techniques

The study has been conducted in the following way.

4.2.1 Finding Root Cause

Five whys lean tools have been used to find the root cause of the problem. It deals with 5 whys worksheet and asks 5 times why simultaneously from the top level problem. After analyzing the root cause it has been understood that the foundry shop cannot make enough molds to meet delivery targets. Fig. 5 describes five whys worksheet. Therefore, the study has been concentrated in the foundry shop.

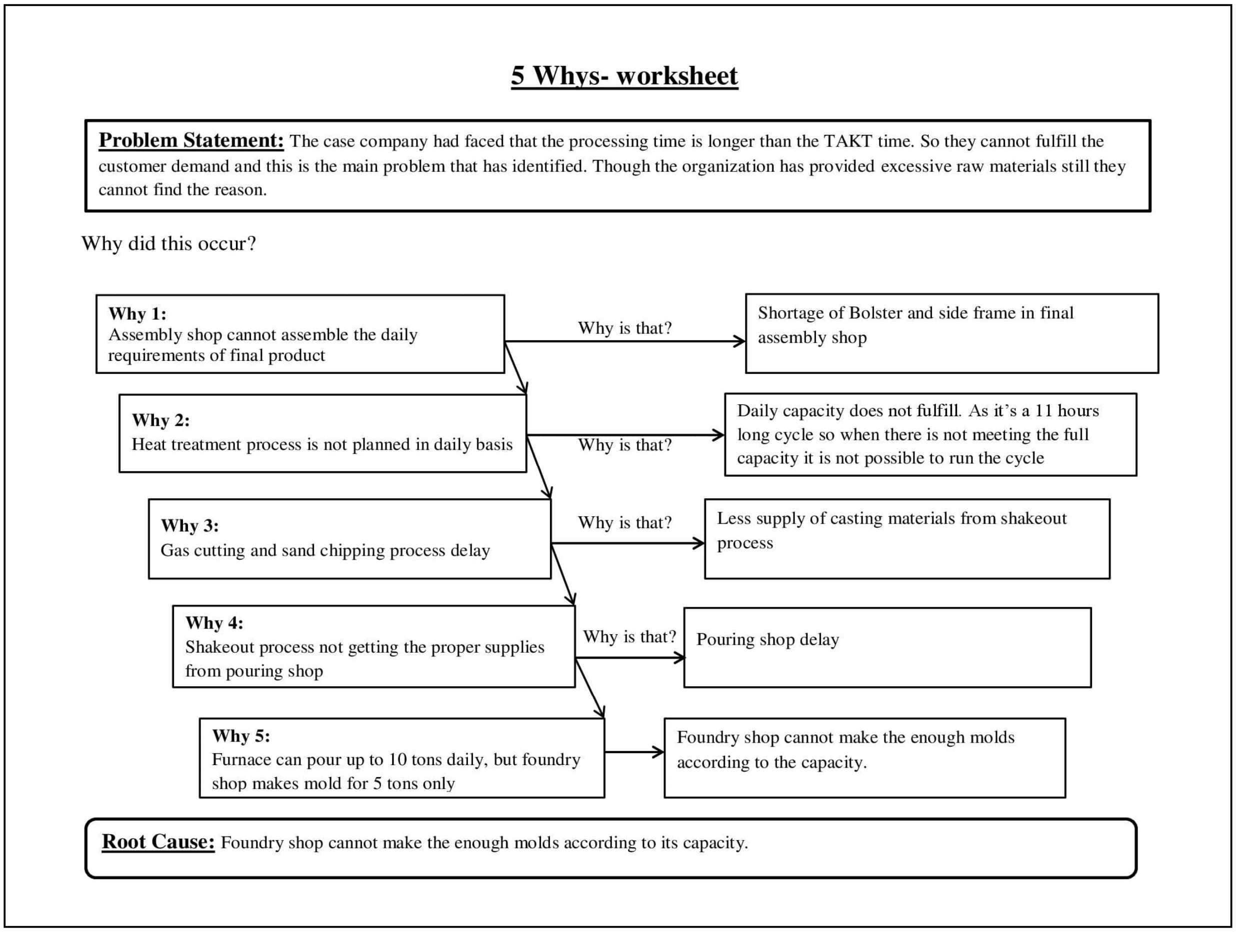


Fig. 5. Five Whys worksheet

4.2.2 Routing sheet of Foundry shop

A route sheet is a blueprint or map of a manufacturing process in a production unit that specifies the exact route or sequence to be followed during the process. For foundry shop a route sheet already exists (Fig. 6) and the same can be considered as precedence diagram of the processes, which outlines the steps required to complete a certain task in the manufacturing or production process. After each action, the task time of the product are recorded and shown in Table 1.

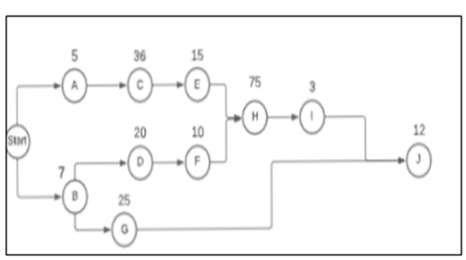


Fig. 6. Precedence Diagram of foundry shop

Table 1
Task time before implementation of LMT

Sl. No.	Task Name	Predecessors	Task Time (Min)
A	Core Sand Preparation	–	5
B	Facing Sand preparation	–	7
C	Core making	A	36
D	Drag Making	B	20
E	Core Collection	C	15
F	Mold painting	D	10
G	Cope making	B	25
H	Core insertion	E,F	75
I	Final checking and box marking	H	3
J	Cope and Drag assembly	I,G	12

4.2.3 *Study on task time*

A stopwatch time study has been conducted at foundry shops to determine how long it takes to complete each task listed in Table 1. For each task, five observations have been taken to determine average observed time and the same has been compared with available standard time. Table 2 presents the study result.

Table 2
Time study for mold making process in foundry shop

SI No.	Activity description	Average observed time including wastes during working (Min)	Standard time (Min)	Ratio of standard time to average observed time
1	Core Sand Preparation	5	5	1
2	Facing Sand preparation	7	7	1
3	Core making	36	36	1
4	Drag Making	20	15	0.75
5	Cope Making	25	18	0.72
6	Core collection	15	5	0.33
7	Mold color	10	10	1
8	Core insertion	75	50	0.67
9	Final checking and box marking	3	3	1
10	Cope and drag assembly	12	8	0.67

4.2.4 *Current Value Stream Mapping*

After finding out task time, a value stream mapping of the current state as shown in Fig. 7, is created to identify areas for improvement and activities that spend the most non-value added time (NVA). Current VSM shows that the task of copying, core collection, drag making and core insertion consumes NVA and this needs to be minimized. Here NVA is contributed by unnecessary transportation of material and unnecessary movements.

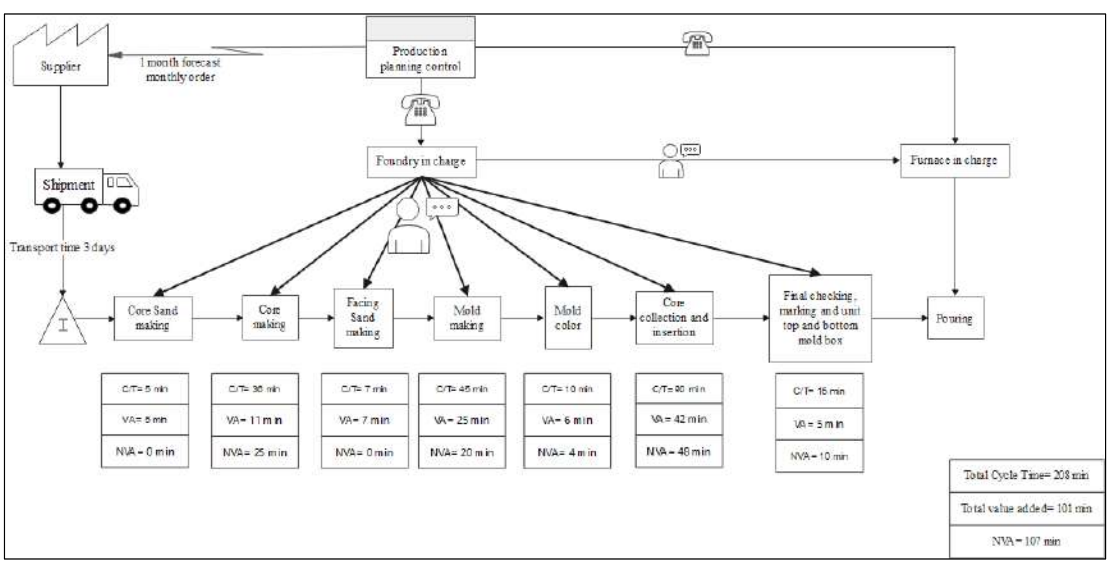


Fig. 7. Current value stream mapping

4.2.4.1 Analysis of current Value Stream Mapping

The summary of observation of current value stream mapping in foundry shop are as follows-

(i) The actual value added time is 101 minutes and the lead time is 208 minutes so it is clear that value added time is 48.55% of total cycle time.

(ii) Due to noise in shop floor, a communication delay exists between overhead crane operator and workers on the floor. It creates a transportation waste in the movement of molding sand, cores etc. to the molding area.

(iii) Presently, to make the molds floor molding technique is being used. Workers suffer from high internal fatigue due to improper working posture (shown in Fig. 8) for core insertion and mold box closing activities. This prevents continuous working of the workers resulting waiting waste. This act as bottleneck to the process.

(iv) TAKT time has been determined using following available information presented in Table 3.

Fig. 8. Current working posture for Core insertion activity

Table 3

TAKT time determination

Available data for activities	Frequency
Customer Order/month	75 Nos. finished good
Raw material procurement	Monthly
Total shift/day	One shift/day
Working day/month	25 days
Available time for working	480 minutes/day (12000 min/month)
Demand per day	(75/25) = 3 Nos. finished good
Major components per finished good	1 bolster and 2 side frames
Daily requirements for mold for 3 Nos. finished good	9 (3 for bolsters and 6 for side frames
TAKT time- (Total available time per day/ demand per day)	(480/9) = 53.33 min.

4.2.5 Line Balancing

Line balancing deals with allocation of workloads to different workstations. Each workstation should get the same amount of time to operate and complete the tasks. From the time study report presented in Table 2, it has been observed that core insertion activity takes a maximum time of 75 minutes and the same is placed in workstation 3. The distribution of other activities into workstations is shown in Table 4.

Table 4

Allocation of activities into various workstations

Workstation	Eligible Task	Task Assigned	Task time	Remaining time (CT=75 min)	Remaining eligible task	Idle time
1	A,B	B	7	68	A,D,G	8
	A,D,G	G	25	43	A,D	
	A,D	D	20	23	A,F	
	A,F	F	10	13	A	
	A	A	5	8	C	
2	C	C	36	39	E	24
	E	E	15	24	H	
3	H	H	75	0	I	0
4	I	I	3	72	J	60
	J	J	12	60	–	

Workstation	1	2	3	4	Total (min)
Available time	75	75	75	75	300
Performance time	67	51	75	15	208
Idle time	8	24	0	60	92
Line efficiency	(208/300)x100% = 69.33%				
Balance delay	[1-(total performance time/total available time)] = 30.66%				

5. Adoption of lean manufacturing techniques

Lean manufacturing techniques have been implemented in the following way to improve productivity.

5.1 Waste Removal

The study reveals that there are three types of major wastes that exist in the operations of the organization. Following proposals have been submitted to remove these wastes systematically.

5.1.1 Transportation waste

In the foundry shop, there are two overhead bridge cranes available for lifting all kinds of heavy load which include supply of molding sand, pattern lifting, mold box lifting, core transfer to mold bed, core lifting for insertion, shakeout of cast items, carrying empty mold boxes etc. Due to noise in the shop floor, the verbal communication between workers and crane operators get disturbed frequently resulting in delay and NVA in many tasks like- mold making, core collection, core insertion process etc. To overcome this Andon light tool of lean has been implemented in the shop floor. Different work stations have issued different colors of light which helps the crane operator to detect the call from a particular workstation.

5.1.2 Unnecessary Motion

Most of the activities in the foundry shop are conducted manually. So the motion of the worker is a vital part as they work for a long time. Lean manufacturing is a business approach that prioritizes the human being as the most important human element in ensuring the organization's long-term viability (Tortorella et al., 2017). It has been found that the persons who insert core to the core gap of mold and assemble the cope and drag boxes, suffer from a kind of internal fatigue and muscular pain in waist and neck. To avoid improper posture of the workers because of floor molding, it has been proposed to follow bench molding technique with a reduced cycle time. *Waiting*

The transportation waste discussed in 5.1.1 promotes waiting waste also. Sometimes the worker remains idle due to lack of seamless transportation flow. To reduce waiting time, the Kanban system has been implemented.

5.2 Proposed State of VSM

After line balancing, the proposed state of VSM depicts product flow without the sources of NVA activities. The proposed state of VSM (shown in Fig. 9) is created using the present VSM model and offers suggestions for enhancing the company's current condition. It concludes that the NVA time got reduced to 56 minutes from 107 minutes and lead time reduced to 157 minutes from 208 minutes.

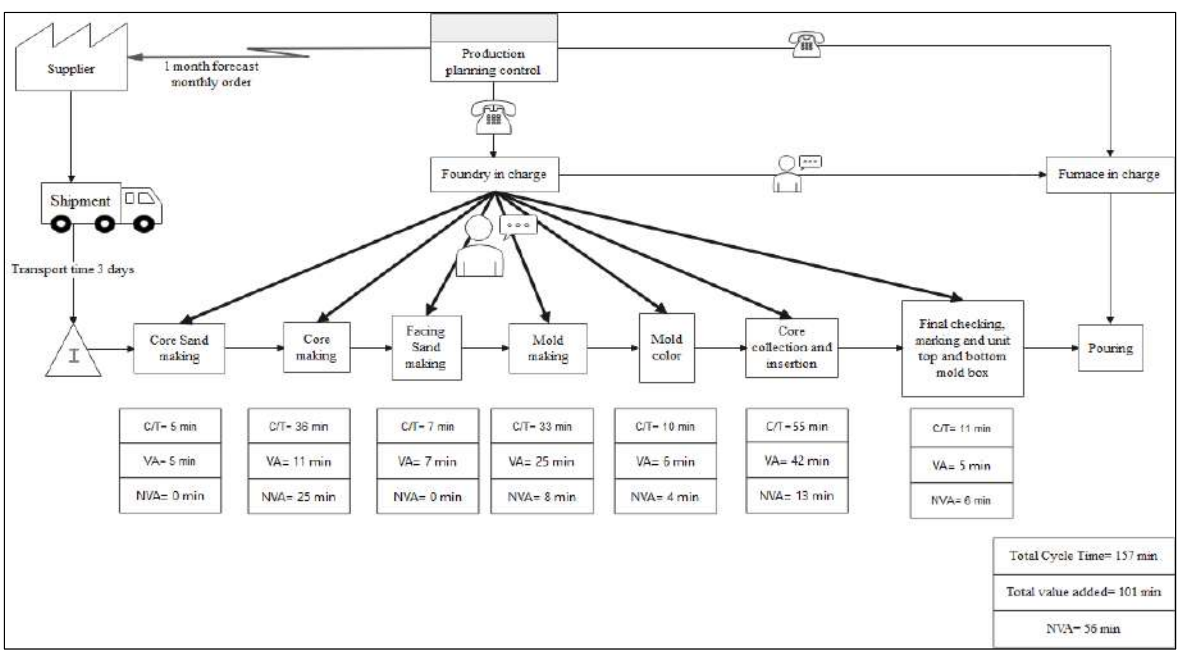


Fig. 9. Proposed state of VSM

5.3 Proposed Line Balancing

After implementing lean tools and reducing NVA, task times for activities at foundry shops have been checked and presented in Table 5. The modified activity distribution in the workstations is shown in Table 6 which also includes improvement in line efficiency and reduction in balance delay.

Table 5

Task time after implementing LMT

Activity	Task Name	Predecessors	Task Time (Min)
A	Core Sand Preparation	–	5
B	Facing Sand preparation	–	7
C	Core making	A	36
D	Drag Making	B	15
E	Core Collection	C	5
F	Mold painting	D	10
G	Cope making	B	18
H	Core insertion	E,F	50
I	Final checking and box marking	H	3
J	Cope and Drag assembly	I,G	8

Table 6

Modified allocation of activities into various workstations

Workstation	Eligible Task	Task Assign	Task time	Remaining time (CT=50 min)	Remaining eligible task	Idle time
1	A,B	B	7	43	A,D,G	0
	A,D,G	G	18	25	A,D	
	A,D	D	15	10	A,F	
	A,F	F	10	0	A	
2	A	A	5	45	C	4
	C	C	36	9	E	
	E	E	5	4	H	
3	H	H	50	0	I	0
4	I	I	3	47	J	39
	J	J	8	39	–	
Workstation		1	2	3	4	Total (min)
Available time		50	50	50	50	200
Performance time		50	46	50	11	157
Idle time		0	4	0	39	43
Line efficiency		(total performance time/total available time) x100% = (157/200) x100% = 78.5%				
Balance delay		[1-(total performance time/total available time)] = 21.5%				

5.4 Layout Optimization

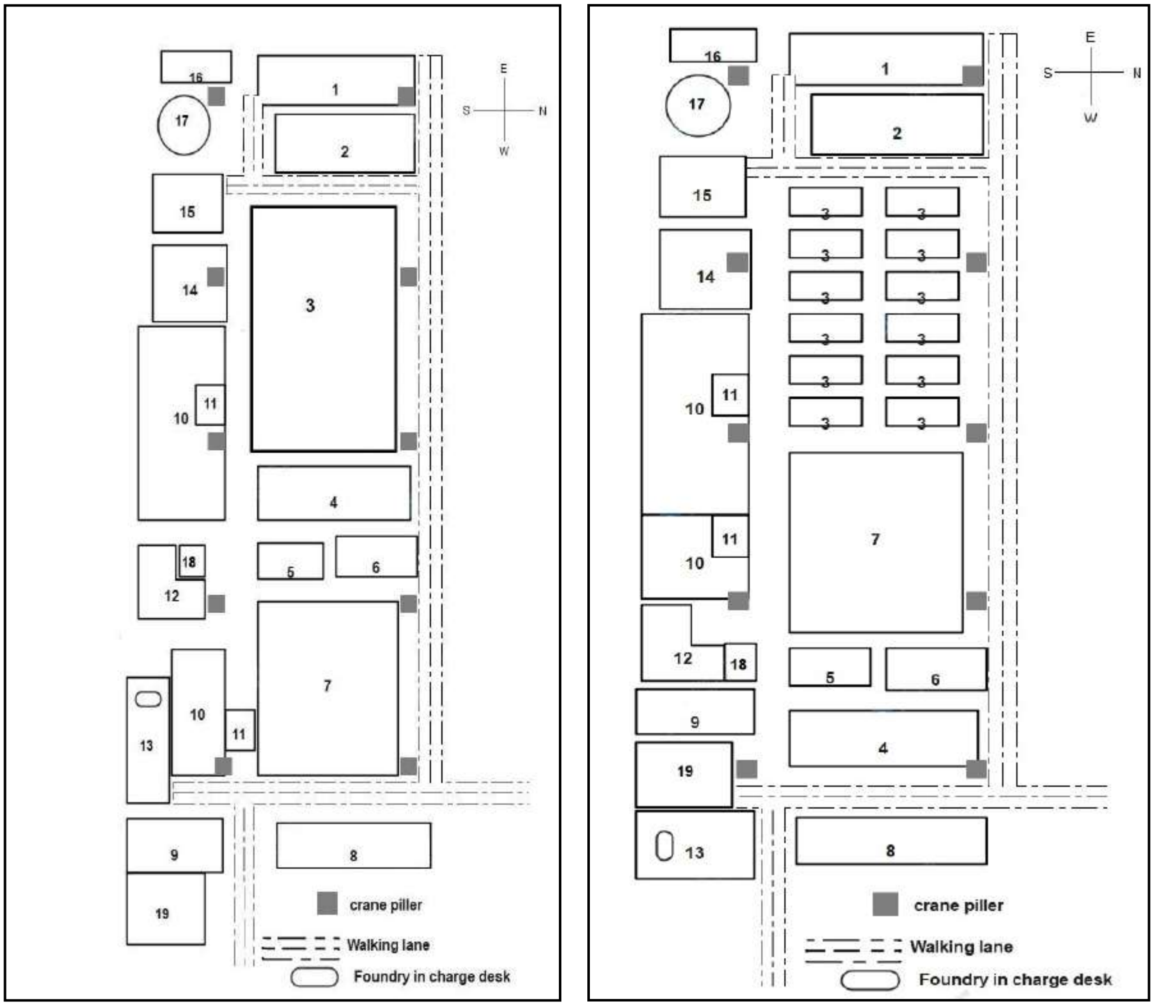
The fundamental goal of layout optimization is to reduce material movement between two workstations or machines, increase plant efficiency, improve material flow, and reduce material transportation time and cost.

5.4.1. Existing layout

The current layout arrangement of the foundry is based on old productions and demand schedules. There has been a shift in production and demand patterns in recent years. Demand is growing every day, but the layout is outdated, and it needs to be updated to meet current demands.

5.4.2. Proposed Layout

To make a smoother material flow, few modifications in the existing layout have been proposed. According to the existing layout, the proposed layout has been optimized. The proposed layout cuts the time it takes to get from one workstation to another. The proposed layout has been planned keeping in mind the constraint of overhead crane movement. The existing and proposed foundry layout has been shown in Fig 10.



Exiting layout **Proposed layout**

Labels

1. Furnace Raw material
2. Molding box store
3. Casting bed
4. Before shakeout mold box stack
5. Shakeout bed (Vibrator)
6. Temporary storage for finished casting
7. Ramming area
8. Pattern store
9. Sand Muller
10. Core making area
11. Sand Muller
12. Baking sand store
13. Cabin for foundry- in- charge
14. Waste material store
15. Laboratory
16. Electric room
17. Furnace
18. Control panel for shakeout process
19. Fresh new sand store

Fig. 10. Existing and proposed layout

6. Results and Discussions

This research primarily focuses on waste removal using techniques of lean manufacturing like VSM, line balancing and layout optimization etc. to identify the bottleneck and removal of NVA activities from the system, to reduce the lead time and hence to improve productivity. After the study, following outcomes have been observed through implementation of lean tools:

(i) Line balancing reduces the cycle time of the processes below the TAKT time and reduces the idle time of the work-station. After implementation of lean, using line balancing, the cycle time becomes 50 minutes per workstation which matches with TAKT time of 53.33 minutes.

(ii) The proposed layout has been arranged such that the time of travel between two workstations can be reduced and crane movement becomes as low compared to earlier practice.
(iii) From the final outcomes it is clear from line balancing calculation that the efficiency of the line has increased up to 78.5% from 69.33% and balance delay reduces up to 21.5% from 30.66%.
(iv) VSM helps to reduce the lead time of foundry shops from 208 minutes to 157 minutes, allowing them to satisfy customer demand on time.

7. Conclusions

The study deals with productivity improvement in a medium-sized manufacturing industry through the application of various lean and industrial approaches without any extra cost, any extra resources and extra manpower. On the basis of VSM and time study, the VA and NVA actions are separated. The bottleneck NVA activities have been removed from the current VSM to meet delivery targets.

This study has been limited to the application of value stream mapping, layout optimization and line balancing in a particular industry and several improvements have been observed without changing their old methods, manpower without extra cost. Additional lean tools, such as 5S, TPM, Single minute exchange of Die (SMED), and others can be used to extend this in the operations of the organization with a view to improving productivity to the highest extent.

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