



# JUST-IN-TIME (JIT) IMPLEMENTATION IN FOUNDRY DIVISION USING MIX MODEL MANUFACTURING AND INVENTORY HANDLING SYSTEM

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## ABSTRACT

*In this study, a foundry division which is producing a variety of products like pump parts, gears, cams, lathe beds, and engine housing is taken. But the foundry cannot able to meet the customer's demand for a variety of the same product. The main problem is*

*the layout of the foundry is randomly arranged and the inventory holding of the finished goods is also not optimized. To overcome these problems lean tools like mix model manufacturing, value stream mapping, and inventory handling system are used. Just-in-Time (JIT) is also implemented to reduce the manufacturing time of the products. The result that is obtained by implementing the lean tools is the inventory holding cost is reduced drastically, the layout change reduces the work-in- progress inventory. These methods are most suitable for a foundry division that is unable to produce a variety of the same products in the same manufacturing line.*

**Keywords:** Just-in-Time (JIT), Foundry, Mix Model Manufacturing, Value Stream Mapping (VSM), X Matrix, Inventory handling system.

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## 1. Introduction

A foundry is a factory that produces metal castings. Metals are cast into shapes by melting them into a liquid, pouring the metal into a mold, and removing the mold material after the metal has solidified as it cools. The most common metals processed are aluminum and cast iron. However, other metals, such as bronze, brass, steel, magnesium, and zinc, are also used to produce castings in foundries. In this process, parts of desired shapes and sizes can be formed. Foundries are one of the largest contributors to the manufacturing recycling movement, melting and recasting millions of tons of scrap metal every year to create new durable goods. Other than casting defects foundry industry also faces some other issues like the alignment of the machines are mostly randomly arranged, the variation in the design also delays the manufacturing process, this variation in design also makes the production line complex, and the effectiveness of the storing goods is also not proper.

Just-in-time manufacturing, or JIT, is a production strategy designed to meet demand as exactly as possible while minimizing waste and extra costs associated with creating surplus goods. It is very similar to Lean manufacturing and the terms are sometimes used interchangeably. Also known as short-cycle, continuous- flow, or lean manufacturing, JIT aims

to produce exactly what, when, and how much was ordered – either by the next workstation sequence or the customer. Accurate demand forecasting is thus a prerequisite of this production model. JIT is geared toward eliminating waste arising from inefficient manufacturing. This results in reduced standing inventory, labor costs, storage space, throughput time, etc. In addition to the JIT, another lean tool Mixed Model Production is the practice of assembling several distinct models of a product on the same assembly line without changeovers and then sequencing those models in a way that smoothes the demand for upstream components. The objective is to smooth demand on upstream work centers, manufacturing cells, or suppliers and thereby reduce inventory, eliminate changeovers, and improve kanban

operation. It also eliminates difficult assembly line changeovers. Mixed model assembly, at first glance, seems overly complicated. It presents difficulties in part stocking, setup, skills, training, and general confusion that must be overcome. Another lean tool like inventory management helps companies identify which and how much stock to order at what time. It tracks inventory from purchase to the sale of goods. The practice identifies and responds to trends to ensure there's always enough stock to fulfill customer orders and proper warning of a shortage. Once sold, inventory becomes revenue. Before it sells, inventory (although reported as an asset on the balance sheet) ties up cash. Therefore, too much stock costs money and reduces cash flow. One measurement of good inventory management is inventory turnover. An accounting measurement, inventory turnover reflects how often stock is sold in a period. A business does not want more stock than sales. Poor inventory turnover can lead to dead stock or unsold stock.

Lean manufacturing is a production process based on an ideology of maximizing productivity while simultaneously minimizing waste within a manufacturing operation. The lean principle sees waste as anything that doesn't add value that the customers are willing to pay for. One of the common and convenient ways to implement lean manufacturing is the application of Value Stream Mapping (VSM). Before going into Value Stream Mapping (VSM), first we see what is value? In terms of Lean, the value should always be considered from a customer perspective. The product's value is that the customer is willing to pay. The company's main objective is to reduce the non-value-added activity that the customers are not willing to pay. Value stream mapping (VSM) is defined as a lean tool that employs a flowchart documenting every step in the process. Many lean practitioners see VSM as a fundamental tool to identify waste, reduce process cycle times, and implement process improvement. VSM is a workplace efficiency tool designed to combine material processing steps with information flow,

along with other important related data. VSM is an essential lean tool for an organization wanting to plan, implement, and improve while on its lean journey. VSM helps users create a solid implementation plan that will maximize their available resources and help ensure that materials and time are used efficiently.

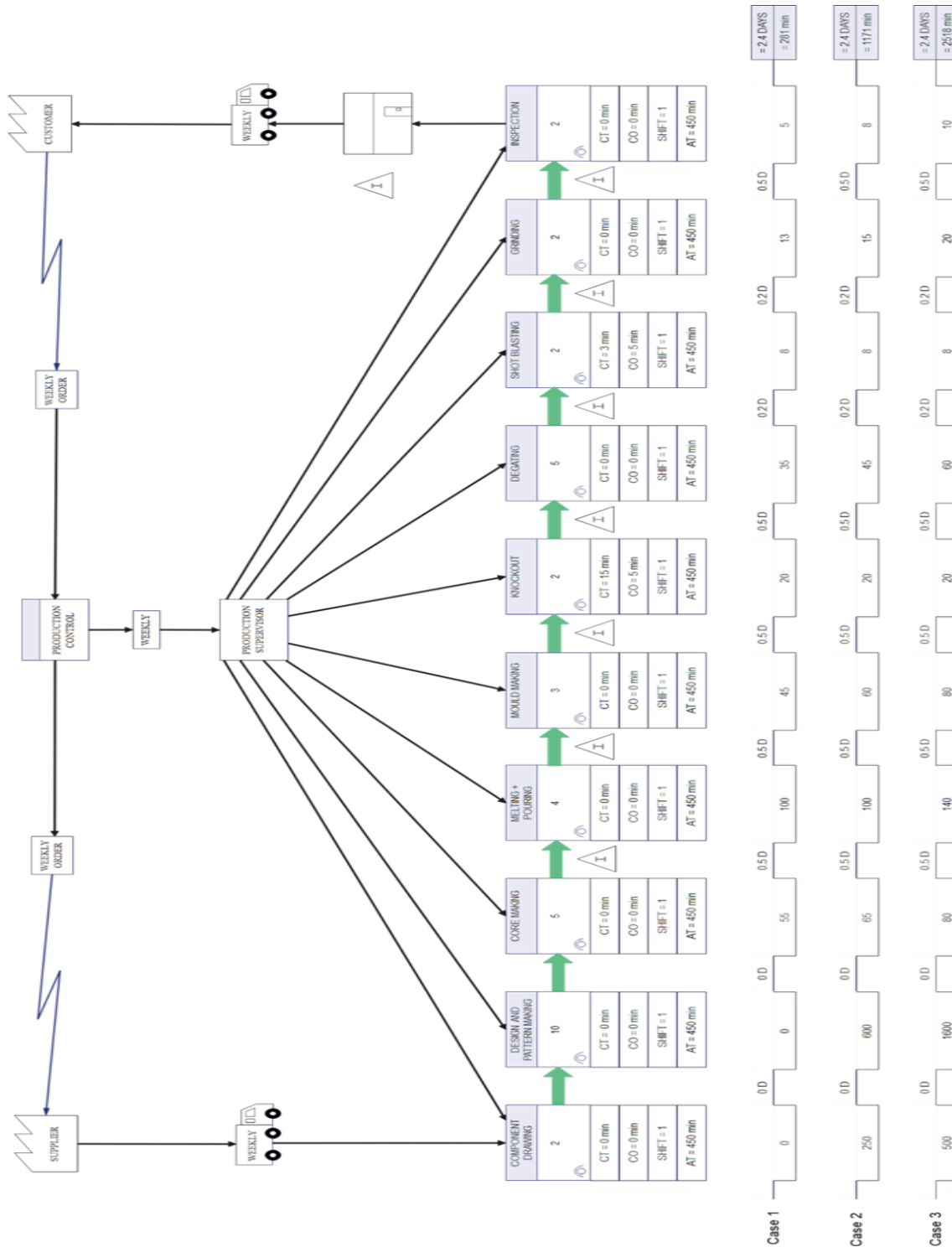


Fig. 1. Current state VSM for three cases

The above Value Stream Mapping (VSM) is in Fig.1. shows the three different product groups and their process flow, Cycle Time (CT), Change-over Time (CT), and total processing time. The industry runs for 1 shift (8 hours). These cases are classified based on existing products, existing products with minor changes, and totally new products.

### **Case 1**

The manufactured products which are already existing (lathe bed, engine housing) are categorized as case 1. These products are frequently manufactured without any changes in their design. There is no time taken for component drawing and pattern preparation because these are already available in the industry. This will reduce the total processing time significantly for the existing products. The total processing time for the existing products takes around 281 minutes which is smaller than the other two cases because of the existing design and pattern.

### **Case 2**

The products (impeller, impeller casing, motor housing, and motor covers) which are already existing and have some minor changes are categorized as case 2. These products take some time for component drawing and the pattern-making process compared to case 1. These products with some modifications take some time in processes like core making, mold making, degating, and quality checking compare to the existing products. The total processing time for case 2 increased because of some changes in the design and pattern-making process and it takes around 1171 minutes.

### **Case 3**

The new products are categorized as case 3. These new products have a new design compared to the other two. Because of that, the whole process from start to finish for these new products takes a lot amount of time to complete the whole manufacturing process. For case 3 products the total processing time takes around 2518 minutes because of the design and pattern-making operations.

From the above current state VSM, the total lead time for the 3 cases is higher than the total processing time. The inventory between the processes takes lots of time to move into the next one. The movement of material is also not optimized and the varying demand for the variety of the same product will also make some confusion in the manufacturing process.

Identifying suitable lean tools and how to implement them to overcome the above-mentioned problems, and getting measurable results from it is not that easy. For a structural way of implementing the lean tools literature reviews similar to the case study are needed. Amir Azizi et al.[1] In their study, they use VSM in PCB assembly lines to reveal obvious and hidden

waste that affected the productivity of smart tag production. This hidden waste was related to the high changeover time at the insertion process of the PCB assembly line and induced high WIP. The improvement process is designed to reduce the WIP and lead time using SMED and Kaizen techniques, K. Venkataraman et al. [2] In their study they used VSM in the Crankshaft manufacturing cell to eliminate 8 non-value-adding wastes like overproduction, waiting, unnecessary transport movement, defects, and unused employee creativity from the manufacturing system and also to create product mix flexibility in the manufacturing cell. Rahani AR et al. [3] In their case study, they use VSM to improve the approach in LP initiatives as it reveals obvious and hidden waste that affected the productivity of D45T production. There is a significant amount of the time products spent on the production system usually was waiting and non-value added. Quantitative evidence showed that many of the Lean tools have an expected impact related to the reduction of this waiting time.

Parthana Parthanadee et al. [4] This article demonstrates the uses of VSM with computer simulation techniques to improve the production efficiency of roasted and ground coffee manufacturers in Thailand. VSM was used to map the current state of the production system to identify areas for improvement. Analysis of the current state of VSM led to improvement solutions which included sharing the resources (roasting machines) and establishing a workforce management plan that rescheduled the tasks for some underutilized operators and pooled all manual operators to assist in the bottleneck sorting operation after their tasks had been completed. K. L. Jeyaraj et al. [5] Through this case study, the existing stage of manufacturing is mapped with the help of VSM process symbols, and the biggest improvement areas like excessive TAKT time, production, and lead time are identified. Some modifications in the current state map are suggested and with these modifications, a future state map is prepared. Further TAKT time is calculated to set the pace of production processes. This paper compares the current state and future state of a manufacturing firm that witnessed a 20% reduction in TAKT time. S.A. Torabi et al. [6] Through this case study, they use the linear programming model with improved discriminating power that can cope with both quantitative and qualitative criteria in an efficient way by applying a common weight approach. Although most of the existing methods in the literature just take quantitative criteria into account for ABC analysis, the modified model accounts for both quantitative and qualitative criteria simultaneously, which is very essential for a comprehensive and realistic ABC inventory classification.

Ruud H. Teunter et al. [7] In this paper, they show (for three large real-life datasets) that the application of both demand value and demand volume as ABC ranking criteria, with

fixed service levels per class, leads to solutions that are far from cost optimal. The new criterion is also more general in that it can take the criticality of SKUs into account. Managerial insights are obtained into what class should have the highest/lowest service level, a topic that has been disputed in the literature. Mohamed Radhouane Douissa et al. [8] In this paper, the ABC inventory classification problem will be tackled as an assignment problem, i.e. an inventory item will be classified to the category with which it has the most similar characteristics. For this purpose, the PROAFTN method will be used to classify each inventory item into a specific category. John Magnus Morton et al. [9] This paper presents the design and implementation of a system for extracting JIT trace information from the Pycket JIT compiler. We define three increasingly parametric cost models for Pycket traces. We determine the best weights for the cost model parameters using linear regression. They evaluate the effectiveness of the cost models for predicting the relative costs of transformed programs.

JózsefVörös et al. [10] This paper analyzes the characteristics of the total cost as a function of demand and suggests how to determine the optimum volume (the demand) in the contracts. It is shown that the minimum point of the total cost as a function of demand decreases in backloging cost. A. S. Aradhye et al. [11] The main objective of this research is to make use of a case study to present various issues regarding the implementation of JIT in the service industry. This case study also shows the benefits of a reduction in the waiting period by employing JIT. The conclusion of this research indicates that the JIT system is successful and operating the JIT system leads to many advantages to the case industry. Maria Anna Huka et al. [12] This paper deals with new opportunities of Industry 4.0 applications for capacity planning on mixed-model assembly lines for industrialized house buildings. They formulate a linear programming model for capacity planning on several parallel production lines and show how this model is fed with accurate data. The solution of the linear program in turn generates a detailed allocation of personnel and workload assignment for a given planning period. We discuss the planning approach and describe the implementation in a real-world environment. Parisa Sadeghi et al. [13] This paper addresses a new Mixed-model Assembly Line Sequencing Problem in the Footwear industry. This problem emerges in a large company, which benefits from advanced automated stitching systems. However, these systems need to be managed and optimized. Operators with various abilities operate machines of various types throughout the stitching lines. In different quantities, the components of the various shoe models, placed in boxes, move along the lines in either direction. The work assumes that the associated balancing

problems have already been solved, thus solely concentrating on the sequencing procedures to minimize the make span.

Sebastian Eberlein et al. [14] This paper presents an appropriate pull principle, which was developed and evaluated through a simulation study conducted at a mixed-model wing assembly line for large passenger aircraft. It is based on aggregating tasks into “pull units” with defined minimum work content. The presented simulation results show the principle’s potential to implement pull and significantly reduce work in process in the described manufacturing environments. Xuemei Liu et al. [15] This paper presents a new approach to coupling line balancing and buffer allocation for stochastic mixed-model assembly lines. Three types of complexity are defined, that is time diversity complexity for a single station, time diversity complexity for a whole line, and time stochastic fluctuations complexity. An integrated optimization model for line balancing and buffer allocation is established with the objectives of maximizing productivity and minimizing complexity and total buffer capacity. Barnabè, F. et al. [16] The purpose of this paper is threefold: first, to highlight the potential role played by Lean strategy tools for strategic planning and management, particularly about the Hoshin Kanri policy deployment system and the “focus, alignment, integration, and review” (FAIR) method; second, to discuss how Lean strategy can be operationalized, specifically relying on the X-Matrix reporting tool; and third, to explore how simulation techniques, in the form of role-playing (RP), may support the aforementioned operationalization of Lean strategy while at the same time promoting policymaking and knowledge sharing.

The above literature review shows that the concept of lean tools may be simple but, it is not that easy when it comes to real-time implementation. The tools like Mix model manufacturing cannot be easily implemented in an industry, especially in a foundry division, and for that, a lot of background work is needed to be done. Finding out the products that are having variety at the same time the demand for that product is also stable. Observing the cases that are related to this one helps to implement the correct lean tools in an effective way. Since the industry wants to reduce the lead time of the product JIT needs to be implemented. For implementing JIT forecasting future demand is necessary. Layout optimization is not an easy task when it comes to the foundry industry. The result that is obtained from this study is mostly suitable for all foundry division that wants to optimize the workshop layout and reduce the inventory holding cost.

## 2. Methodology

For this case study first, an X matrix is created to visually see the relationship between the process, product, and long-term goals, and the metrics that are needed to be improved are identified. The X matrix also helps to identify the departments that are directly influencing the metrics that are needed to be improved. ABC inventory handling system helps to reduce the inventory holding cost of the finished goods. Product grouping helps to identify the products that are changing their variety based on the demand. The result that is obtained from the product grouping is then used in mix model manufacturing for reducing the manufacturing time of the products with some variety. Material movement is help to change the layout of the foundry division based on the material movement that is observed for the various products. Finally, Just-in-Time (JIT) is implemented.

### 2.1 X Matrix

This seems to be what many people focus on when performing hoshin kanri. This is one of many tools we use to craft our deployment plan. There seem to be many styles of X matrixes. Find one that you think would fit your organization and modify it to better meet your needs. In the X matrix, we put the three to five-year strategic initiatives at the bottom. The top focus initiatives for the near term (one to two years) are placed in the left-hand-side boxes. Projects and initiatives for this year are placed along the top. Don't forget to put in projects that have carried over from last year and items you will be working on regardless of whether they are part of your original plan. Measures and metrics go on the right-hand side. We try to use a balanced scorecard approach with a mix of leading, lagging, and real-time indicators also known as key process indicators. Try using a balanced approach so you do not drive the wrong behaviors. On the right-hand side, we also put departments or functional areas within the organization to help determine who should lead projects or be on the team. You normally don't fill in the X matrix all at once, and it may take a few iterations to complete it. When you do compare each of the items to see whether there are any correlations between them. As a team, determine whether there is a very strong correlation, an important correlation, a weak correlation, or no correlation. This is another leap forward as you start to see how your strategic initiatives, focus strategies and projects, and measures and metrics are all in concert with one another. This allows all employees to visualize how their work has an impact on the strategic direction.



## 2.2 ABC inventory handling system

ABC's method of inventory control involves a system that controls inventory and is used for materials and distribution management. It is also known as selective inventory control or SIC. ABC analysis is a method in which inventory is divided into three categories, i.e. A, B, and C in descending value. The items in the A category have the highest value, B category items are of lower value than A, and C category items have the lowest value. Inventory control and management are critical for a business. They help to keep their costs under control. The ABC analysis helps the business to control inventory by letting the management focus on the highest-value goods (the A-items) and not on the many low-value goods (the C-items). ABC inventory analysis is based on the Pareto Principle. The Pareto Principle states that 80% of the sales volume is generated from the top 20% of the items. It means that the top 20% of the items will generate 80% of the revenue for the business. It is also known as the 80/20 rule. This method is significant to identify the top category of inventory items that generate a high percentage of yearly consumption. It helps the managers to optimize the inventory levels and achieve efficient use of stock management resources. The products are classified into ABC based on their cumulative percentage of the total value. For this industry considering the product variety and demand the classification is done based on the following criteria.

- A Class –  $0\% \leq \text{cumulative \%} \leq 50\%$
- B Class –  $51\% \leq \text{cumulative \%} \leq 80\%$
- C Class –  $80\% \leq \text{cumulative \%} \leq 100\%$

Table 1. Products Total Value

Product No.	Product	Demand (Nos.)	Price per unit (Rs.)	Total Price (Rs.)
1	Impeller	400	300	120000
2	Impeller Casing	400	350	140000
3	Motor Back and Front Cover	400	250	100000
4	Motor Housing	400	300	120000
5	Cams	100	400	40000
6	Bearing Housing	150	300	45000

7	Gears	200	400	80000
8	Lathe Bed	20	15000	300000
9	Engine Block	50	4000	200000
			Total	1145000

Table 2. ABC Inventory Classification

Product No.	Total (Rs.)	% Of Total Value	Cumulative %	Inventory Class
8	300000	26.2009	26.20087336	A
9	200000	17.4672	43.66812227	A
2	140000	12.2271	55.89519651	B
1	120000	10.4803	66.37554585	B
4	120000	10.4803	76.8558952	B
3	100000	8.73362	85.58951965	C
7	80000	6.9869	92.57641921	C
6	45000	3.93013	96.50655022	C
5	40000	3.49345	100	C

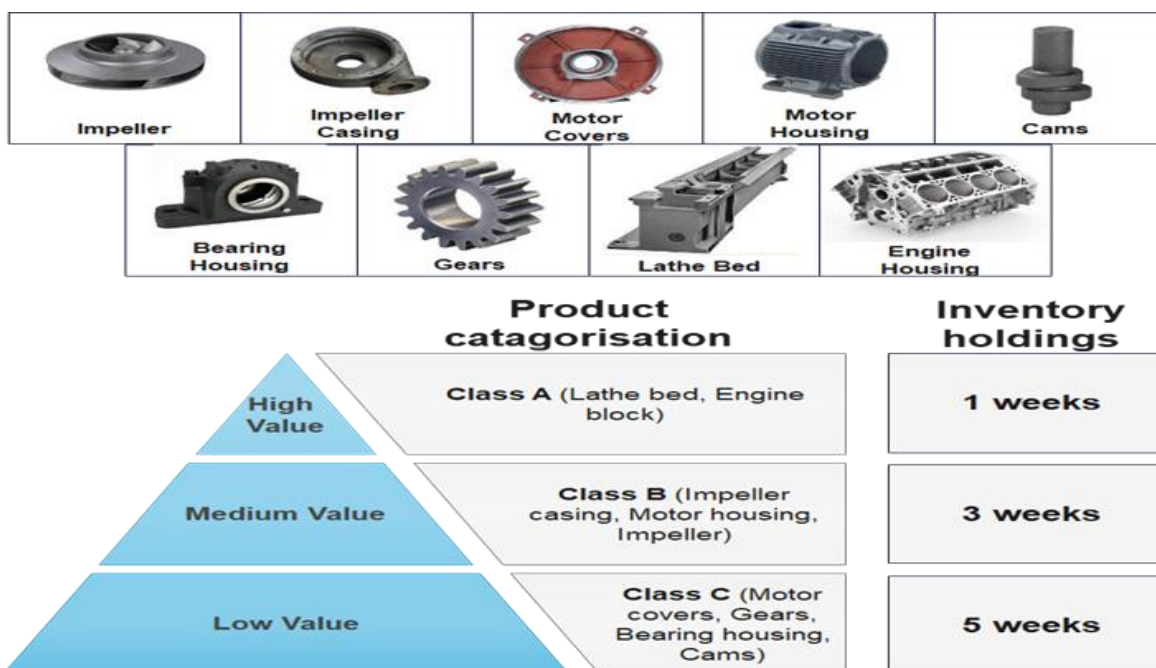


Fig. 3. ABC Classification and Inventory Holding Time

The demand, unit price, and total price of the individual components are shown in Table 1. Table 2. shows the products are sorted based on the cumulative percentage of the total value. The products are categorized into 3 classes based on their values and the demand requirement

is shown in Fig.3. The high value products like lathe beds and engine block products are less in quantity and their unit price is high, because of that these Class 1 products are in the inventory for almost 1 week of time to reduce the inventory holding cost. Medium value products like impellers, impeller casing, and motor housing are in the inventory for almost 3 weeks, these products have a high quantity and the unit price is also average compared to others. Finally, low value products like motor covers, gears, bearing housing, and cams have less quantity and less unit price. So, these Class C products are in the inventory for a long time compared to others because of their low value.

### 2.3 Product Grouping

Based on the demand the products are categorized into three runner, repeater, and strange (RRS). Runners are the most often repeated and standardized tasks, repeaters are less often repeated but fairly standard, and strangers are once in a while and with hardly any standardization. Runners require dedicated flow lines and cells with segregated resources, repeater doesn't demand dedicated flow lines the products are rather produced by a customized process schedule, and strangers are miscellaneous products that are produced with a flexible manufacturing system within the plant.

Table 3. Runner, Repeater & Stranger (RRS) Classification

Type	Products	Average Inventory Holding Time
Runner	Impeller Impeller casing Motor back and front cover Motor housing	3 weeks
Repeater	Cams Bearing housing Gears	4 weeks
Stranger	Lathe bed Engine Blocks	1 week

The above Table.3. shows the 3 categories of product classification based on demand. In this case, the stranger products have a high value compared to the other products because these products are held in the inventory for very less time reducing the inventory holding cost. The runner and repeater products have a high demand that they are held in inventory for almost

4 weeks of time. This holding helps the industry deliver the products to the customer in less time.

## 2.4 Mix Model Manufacturing

The runner products like impeller, impeller casing, pump covers, and motor housing are the runner products that are identified from the above product grouping technique. These products are mostly varying in their model based on the customer requirements. The total demand for the 4 runner products for a month is 1600. 3 months demand requirements for those products are observed and shown in Table 4.

Table 4. Demand for 3 months

Model	Month	On Hand	Month 1	Month 2	Month 3
Economy	Impeller	150	200	150	300
	Impeller Casing	200	200	150	300
	Motor cover	200	50	-	200
	Motor housing	200	50	-	200
Standard	Impeller	200	150	250	-
	Impeller Casing	125	150	250	-
	Motor cover	100	300	325	200
	Motor housing	100	300	325	200
Deluxe	Impeller	50	50	-	100
	Impeller Casing	50	50	-	100
	Motor cover	50	50	75	-
	Motor housing	50	50	75	-
Total		1475	1600	1600	1600

The company also has some stock in hand for some of the products, producing a constant number of products in every variety giving the company to meet the customer demand every month without any shortage. This mixed-model manufacturing implementation helps the casting industry to produce different models of the same products in the same production line without any difficulties. The modified production quantity for the three months is shown in Table 5.

Table 5. Mix Model Manufacturing System

Model	Month	On Hand	Month 1	Month 2	Month 3
Economy	Impeller	200	175	175	175
	Impeller Casing	200	175	175	175
	Motor cover	175	200	200	200
	Motor housing	175	200	200	200
Standard	Impeller	150	175	175	175
	Impeller Casing	150	175	175	175
	Motor cover	150	150	150	150
	Motor housing	150	150	150	150
Deluxe	Impeller	50	50	50	50
	Impeller Casing	50	50	50	50
	Motor cover	75	50	50	50
	Motor housing	75	50	50	50
Total		1600	1600	1600	1600

## 2.5 Material Movement (Spaghetti Diagram)

Material handling is integral to the design of most production systems since the efficient flow of material between the activities of a production system is heavily dependent on the arrangement (or layout) of the activities. If two activities are adjacent to each other, then material might easily be handed from one activity to another. If activities are in sequence, a conveyor can move the material at a low cost. If activities are separated, more expensive industrial trucks or overhead conveyors are required for transport. The high cost of using an industrial truck for material transport is due to both the labor costs of the operator and the negative impact on the performance of a production system (e.g., increased work in process) when multiple units of material are combined into a single transfer batch in order to reduce the number of trips required for transport. A spaghetti diagram is defined as a visual representation using a continuous flow line tracing the path of an item or activity through a process. As a process analysis tool, the continuous flow line enables process team to identify redundancies in the workflow and opportunities to expedite process flow. For example, areas, where many walkways overlap, are causes of congestion and delay. Waiting is one of the eight wastes of lean because it is considered "unnecessary motion." The spaghetti diagram helps highlight major intersection points such as these that may not be noticed otherwise

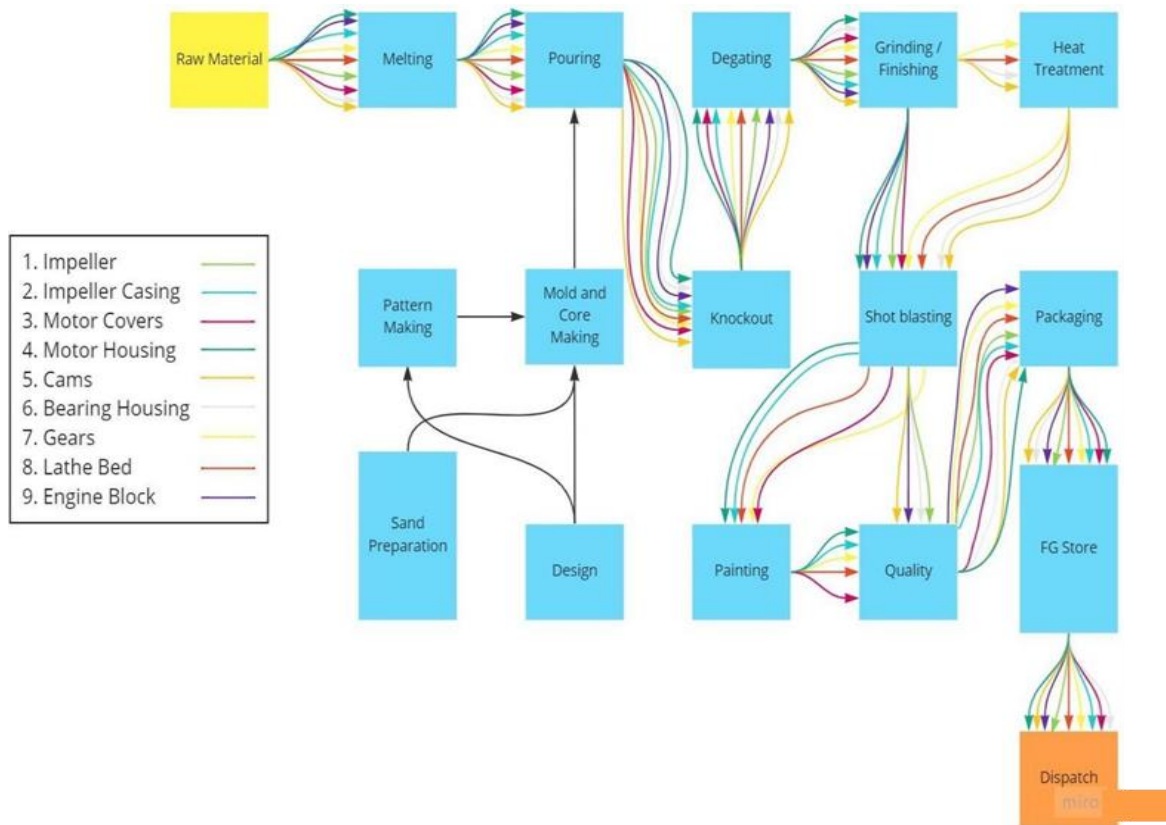


Fig. 4. Current State Spaghetti Diagram

The above current state spaghetti diagram shows the material movement between the processes. The arrangement of processes is not in an effective way, that’s why the inventory between the processes is large and the transportation between the processes also takes more time. The inventory and transportation come under seven deadly wastes. To reduce this deadly waste change in the workshop layout is necessary. After modifying the workshop layout, a future state spaghetti diagram is drawn to visually represent the improvements.

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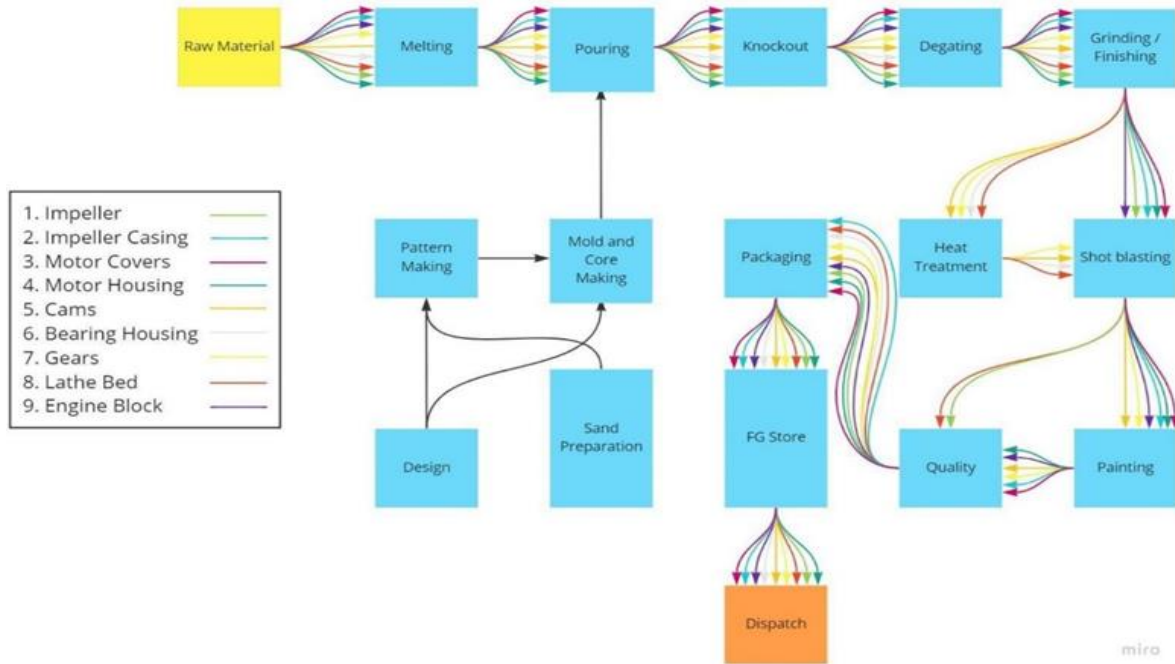


Fig. 5. Future State Spaghetti Diagram

After modifying the current state spaghetti diagram a future state spaghetti diagram is drawn. The workshop layout is changed in a way to reduce transportation and inventory waste. The above material movement diagram shows the clear path that is taken by each product. The main improvement to reduce transportation is to implement the automated knockout system and conveyor between the processes. The change in the layout also helps to improve the multi-product manufacturing in the same production line without any major changes.

## 2.6 Just-in-Time (JIT) Implementation

This foundry facing some issues in inventory management and purchasing of raw materials. A Just-in-Time (JIT) technique is used here to solve the above-mentioned problems. The JIT is implemented by reducing the seven deadly wastes like transportation, inventory, motion, work-in-progress, overproduction, over-processing, and defects. Here the following waste is needed to be reduced for implementing JIT.

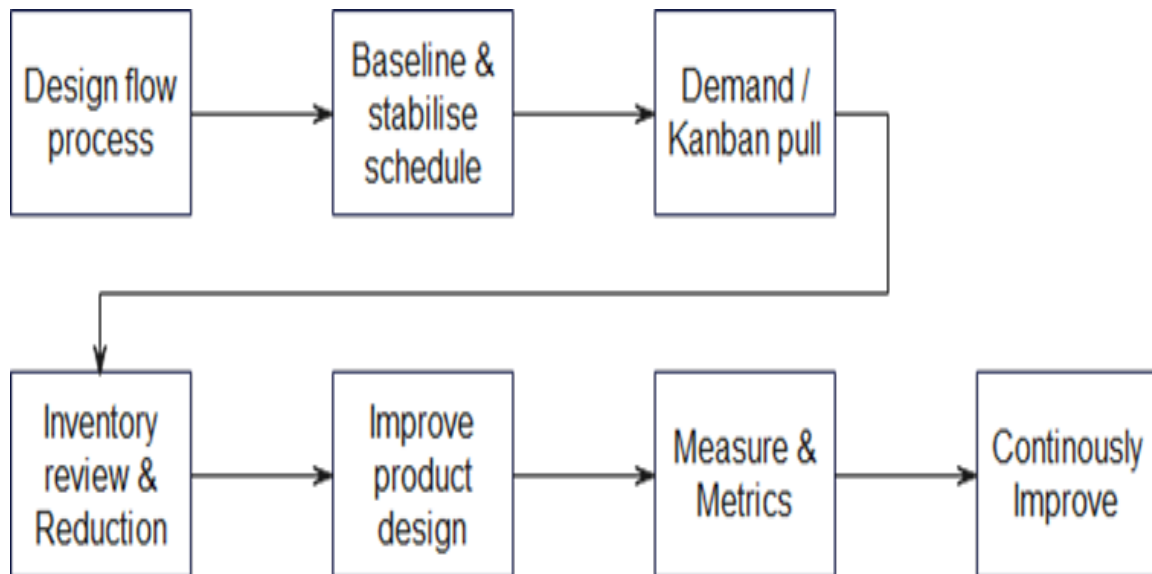


Fig. 6. JIT Implementation Stages

### 2.6.1 Overproduction

Overproduction is manufacturing products in advance of or more than the demand specifies. It's considered the most severe waste by proponents of just-in-time manufacturing because it squanders time, space, and money, all the while masking the other problems within a company's processes. Overproduction can cause a draw on capital for extra materials, unnecessary tools and machinery, additional facility capacity, and excessive inventory space. This creates cash flow constraints and can impair the attention and effort needed for more productive activities.

The overproduction problem here is reduced by forecasting the future demand based on the previous year's demand data. This demand prediction will also help in buying the raw material for the products and assigning the work to the machine effectively. Overproduction reduction can help reduce labor costs by eliminating the unnecessary movement of goods. If the facility prioritizes sufficient quantities of products to manufacture to satisfy customer demand, then employees aren't needed to move excess in and out of inventory.

Table 6. Three Years

Product		Impeller	Impeller Casing	Motor Covers	Motor Housing	Cams	Bearing Housing	Gears	Lathe Bed	Engine Block	
Year 2019	Months	1	357	359	527	442	94	114	205	6	46
		2	354	415	501	401	102	102	229	7	52
		3	403	362	469	509	105	168	207	8	39
		4	402	403	486	477	97	114	232	8	50
		5	403	352	526	394	118	167	223	11	45
		6	384	379	502	441	74	121	241	7	41
		7	367	363	452	411	117	164	248	7	49
		8	369	405	456	429	70	111	206	5	59
		9	359	362	510	452	108	145	202	7	59
		10	409	434	458	396	93	167	194	5	30
		11	410	351	500	445	114	151	245	5	59
		12	355	361	518	448	113	108	216	10	57
Year 2020	Months	1	427	372	549	412	72	136	189	10	33
		2	396	368	489	393	100	139	214	12	36
		3	428	426	506	511	92	128	217	9	31
		4	385	448	503	424	76	173	191	12	46
		5	375	439	459	484	105	139	233	9	33
		6	381	437	530	432	74	151	187	12	37
		7	386	398	530	487	121	151	215	10	40
		8	450	435	510	412	121	165	185	12	30
		9	436	370	534	458	102	117	214	12	35
		10	429	377	480	437	88	123	222	11	55
		11	367	391	473	424	87	146	217	7	42
		12	410	394	476	479	118	144	202	9	34
Year 2021	Months	1	448	435	507	418	70	120	195	6	51
		2	390	416	485	516	90	152	197	12	50
		3	358	393	487	513	87	163	244	6	54
		4	410	392	521	416	94	166	204	7	48
		5	429	372	452	479	90	141	199	10	42
		6	418	353	480	455	73	163	246	11	48
		7	446	352	476	484	87	136	181	9	46
		8	367	404	493	481	115	125	203	12	41
		9	369	367	482	407	88	168	193	9	30
		10	412	401	521	415	125	169	182	6	58
		11	404	377	522	517	74	147	191	11	59
		12	383	383	546	405	102	121	249	8	59

Demand data (2019, 2020, 2021)

The above Table 6 shows the demand for the products for three years. There are a lot of forecasting methods available to predict future demand. For this case, simple linear regression is used because it is more suitable for linearly separated data, and it is easy to

implement, interpret, and efficient to train. From three years of data, next year's demand is predicted and shown in Table 7. These predicted data show that there is no considerable fluctuation in the demand.

### 2.6.2 Simple Linear Regression

This method fits a straight line by considering two variables (a dependent and an independent variable) and a constant. The dependent variable is the function of the independent variable. Equation (1) expresses the generally used straight-line equation and equations (2) and (3) state the expressions for linear regression using the least squares approach.

$$y = a + bx \tag{1}$$

Where  $a$  is the intercept of the straight line,  $b$  is the slope of the straight line,  $y$  is the dependent variable and  $x$  is the independent variable.

$$\sum y = an + b\sum x \tag{2}$$

$$\sum xy = a\sum x + b\sum x^2 \tag{3}$$

By solving the above two equations, the values of  $a$  and  $b$  can be found. Here,  $x$  is the years to be used for the prediction of the demand.

Table 7. Forecasted demand data (2022)

Product		Impeller	Impeller Casing	Motor Covers	Motor Housing	Cams	Bearing Housing	Gears	Lathe Bed	Engine Block
Months	1	387	395	517	452	93	130	219	9	42
	2	388	396	517	451	93	129	217	9	42
	3	385	394	520	448	92	130	216	9	41
	4	386	394	524	449	92	130	217	9	40
	5	385	393	524	445	91	131	217	9	39

	6	386	395	526	447	89	129	217	9	38
	7	388	394	525	450	90	130	218	9	38
	8	389	393	524	448	89	128	215	10	38
	9	388	391	524	448	89	128	214	10	37
	10	389	391	523	448	87	126	214	10	37
	11	387	389	524	449	87	128	212	10	36
	12	385	386	524	449	85	127	211	10	35

### 2.6.3 Waiting

Waiting to begin one process until another one finishes is ineffective and a colossal waste of time. The flow of all operations should be efficient and continuous. Some estimates claim that more than 90 percent of a product's time in manufacturing is spent waiting. Waiting for a certain process to get completed and moving on to the next one is a major problem in industries. In this case, the waiting time between processes is reduced by changing the workshop layout and improving some processes like automating the knockout operation. The time taken for the drawing preparation for the new products and the minor changes in the existing products is high. To overcome the drawing preparation a well-trained team and outsourcing are used. Another one is waiting for the raw material from the inventory. This problem is rectified using the pull system in the process, it also helps the process to run smoothly without wasting any time.

### 2.6.4 Excess Inventory

Excess inventory typically means that a company has ordered more than the market demands or the demand falls dramatically after the inventory is ordered. Either way, it hurts business because it takes up space and must be managed. Companies often rid themselves of excess inventory by selling it at a reduced cost or tossing it out, either of which can lower profits significantly. This excess inventory of products is getting added to inventory holding cost, a company cannot waste its money on goods that are in inventory. To solve the excess inventory problem in the foundry by forecasting the demand and maintaining the safety stock based on the demand changes.

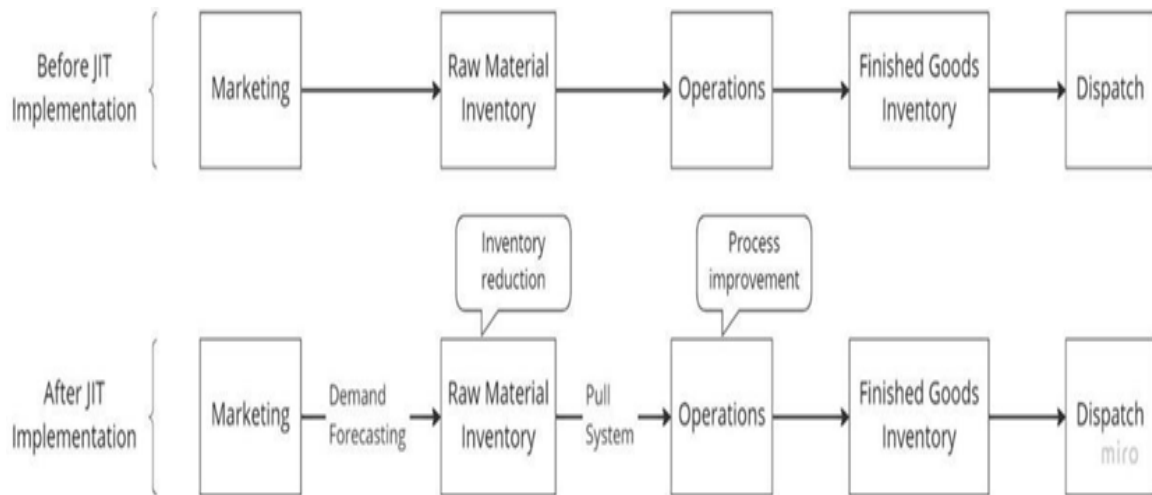


Fig. 7. Process flow – Before & After JIT Implementation

### 3. Result And Discussion

For reducing the Work in Progress (WIP) inventory pull systems are implemented between the raw material to melting operation and sand preparation to mold making operation. The cycle time in knockout operation is reduced by implementing an automated knockout conveyer. The component drawings and design- making operation are improved by using outsources. This will reduce the processing time for the product considerably. Inventory management is also implemented in the Finished Goods (FG) inventory, this will reduce the inventory holding cost of the finished goods and the inventory size is also getting reduced. The degating is an operation that mostly slows down the production line, to overcome this problem a buffer is introduced between degating and the shot blasting operation. This buffer helps the smooth flow in the production line without any waiting. This will reduce the processing time and the WIP inventory. The prediction of the future demand shows that there is no considerable fluctuation in the demand, this will also help in the implementation of mix model manufacturing and optimize the holding of in-hand inventory

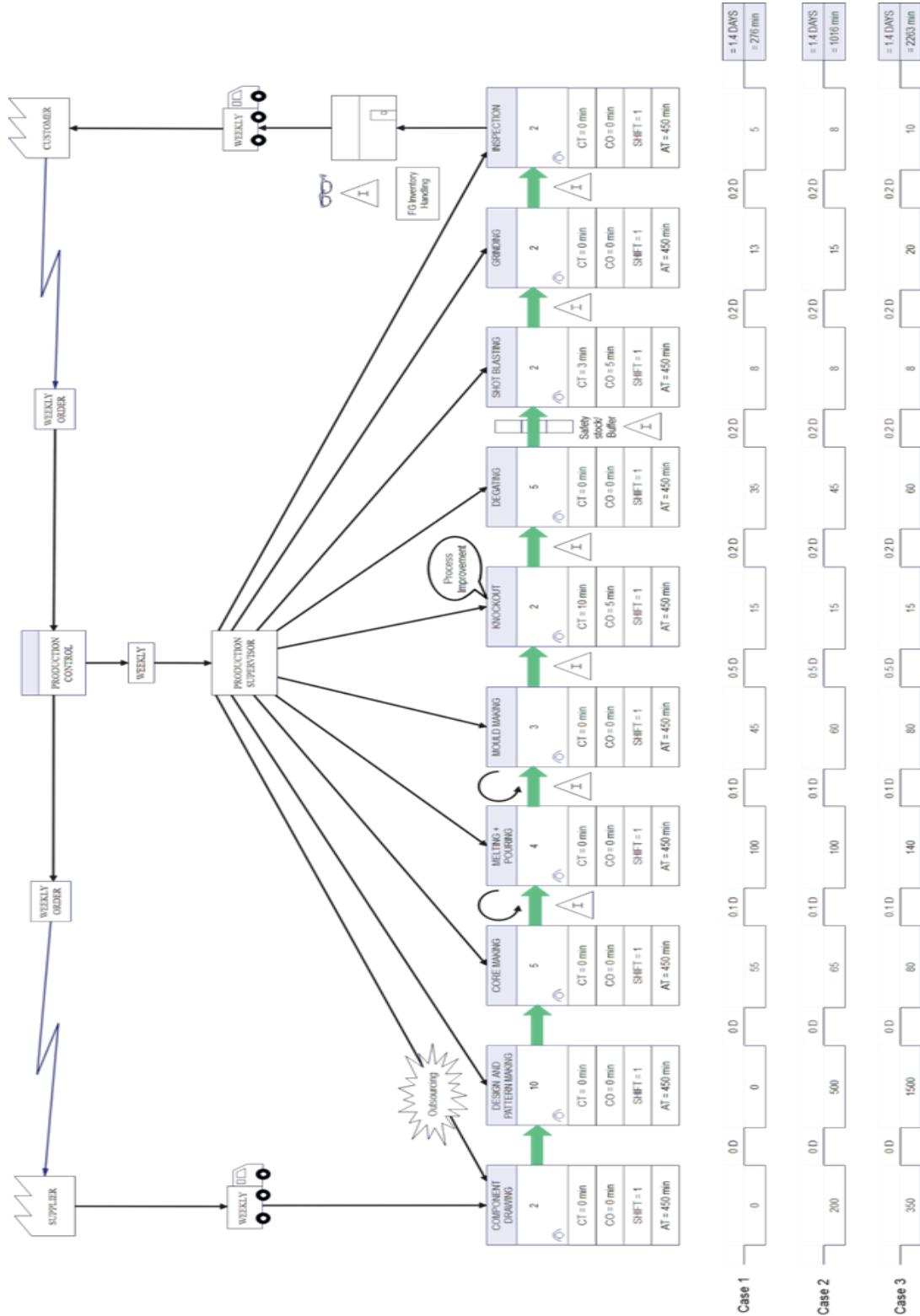


Fig.8 Future state VSM for three cases

After applying all the lean tools that are discussed above a future state Value Stream Mapping (VSM) is drawn to observe the lead time and processing time reduction. The total lead time for all three cases is almost reduced to 1.4 days and the total processing time for the

three cases is also improved. The implemented lean tool in the process is pictorially shown in the above future state VSM, and the VSM is optimized for the future predicted data. After the knockout, the products are needed to send to the degating section as a single unit. Because of that, the process after degating is needed to be waited for a long time, to overcome this problem a buffer inventory is added after the degating operation. The degating operation mostly slows down the process, there is a requirement of new technology are needed to be implemented in this degating station. This will ensure the smooth flow of the product throughout the process without any delay. To optimize the design process Virtual Reality (VR) / Argument Reality (AR) can be used to virtually design the required core parts for the mold and mold design is also optimized for the required product. Senthil Kannan N el at. [17] The implementation of lean tools in an industry will result in the removal of non-value-added process and helps to improve overall efficiency. The lean principles are customized using VSM to improve the foundry processes in the manufacturing of impeller casings. The value-added and non-value-added activities are identified using a current state mapping in the existing process. A future state map is developed by reducing the non-value-added activities thus improving overall efficiency. Addition to the VSM X-matrix is also used to find out where the implementation is necessary and the department necessary for the improvements. The design-making process and the pattern-making are taken more time for the new product and the existing product which are having some minor changes. The time reduction in the theses is directly influenced by the Research and Development department. This design and the pattern-making problem can be solved by getting help from the outside. [18] This work explores new dimensions of corporate strategy with a clear focus on strategic alignment and project definition. Project portfolio management offers processes, tools, and knowledge that help the global alignment of different organizational levels with business. In terms of project portfolio management, the causes of failure can be quite diverse. The development of a tool, namely, the X-matrix can help organizations to define and structure strategic objectives, projects, and metrics, and those responsible

A spaghetti diagram is used to identify the confusion in the process flow using material flow between processes, thus helping in changing the layout of the workshop in an optimized way. The change in the workshop layout helps to implement the mix model manufacturing for producing products with variety without modifying the process flow, this changeover in the layout also helps in reducing the work-in-progress inventory to 1 day. Most of the products do not require heat treatment, so the heat treatment station is moved in a manner that it won't take that much amount of time to get to the station and it won't interfere with the material movement

of the products that don't require head treatment. In addition to the change in layout the spaghetti diagram also helps a firm to use space optimally, this will reduce unused space and help to increase the size of the inventory or develop a new station to improve the process flow. Suganthini Rekha R et al. [19] The passenger vehicle seat manufacturing industry is found to be poorly affected by manufacturing problems due to more cycle time, unbalanced workload, and improper layout. The main aim of this paper is to study the existing system of a seat manufacturing industry and to improve productivity using a lean methodology (spaghetti diagram) without much affecting current working systems. The change in the layout will also help to introduce the conveyer between stations. For example, after the solidification, the products are moved between processes through the conveyor. This will reduce the old transportation time and the machinery transportation equipment like a fork lift and an overhead crane is also minimized. This equipment cost reduction will help the firm to introduce new process machinery to improve the processing time. The introduction of the conveyer system will reduce the number of laborers required for the material movement. The reduction in labor will also reduce the occurrence of error that is made by a human while transportation. The conveyor system is also implemented in the sand preparation unit to move a large amount of sand in less time to the core and mold-making stations. [20] The goal of the inclined conveyor method for particle shape separation is to process a large amount of feed material for recycling technology. The high feed rate has been achieved because the movement of particles is faster than for other previously introduced equipment. The separation performance of the apparatus was tested with foundry sand. A large amount of sand was treated, and various processing capacities were studied experimentally. The feed method was improved from point to line with wide troughs to process the higher feed rate.

Here both the raw material inventory is reduced and the finished goods inventory is improved. The raw material inventory is reduced by predicting future demand and the finished goods inventory is enhanced by using the ABC inventory classification. Other than these two the WIP inventory is also reduced by pull system and process improvements. The inventory management before the shot blasting and the knockout operation are formed in batches to reduce the processing time of the operation. Similar to

the above case the inventory before some machining operations like facing, turning and heating operations are take more time than other operations. To overcome this piling up of the products before these are reduced by introducing another parallel machine, and the waiting time after these processes is reduced by introducing the buffer system or safety inventory before

them. The inventory between each station is also enhanced in a manner to reduce the lead time of the product. This enhancement also helps in the reduction of the number of trips that are taken from one station to another station. The finished goods inventory is also checked frequently for ensuring the ABC inventory classification is correctly followed or not. The arrangement of the FG inventory is taken into consideration for the quick dispatch of the order without any confusion. Szynszal J [21] The paper presents a method for optimizing the inventory level of raw materials under foundry plant conditions using two different

control models. The first model is based on the estimate of an optimal level of the minimum emergency stock of raw materials, giving information about the need for an order to be placed immediately and about the optimal size of consignments ordered after the minimum emergency level has occurred. The second model is based on the estimate of a maximum inventory level of raw materials and an optimal order cycle.

From implementing the above-mentioned lean tools, the processing time of the products is reduced significantly, this will help to deliver the component to the customer in less time. The prediction of future demand will also help to manufacture products prior and deliver them to the customer immediately when the order is getting placed. The high setup and resulting lead times persisted with limited improvement, and this is attributed to the old equipment currently in use. The way forward to redress this may be a major retooling of the plant to modern and efficient standards. The main key feature to improve the JIT implementation is to get the required materials in less time to the supplier. For that, forecasting the future demand is used to predict the demand data based on the raw materials purchased from the supplier before reducing the waiting time. Madanhire I et al. [22] This explores the adaptation of the manufacturing approach to a metal foundry, where raw materials are imported in a highly unstable economy. JIT is applied to improve the cost-effectiveness of operations and quality and to achieve world-class benchmarks. These were reduced by JIT as the adoption of (Total Protective Maintenance) TPM and multi-skilling of various operators initiatives managed to increase the availability of the plant in all the departments. This also meant a flexible deployment of idle resources to busy stations in the plant. Customer feedback is constantly reviewed to ensure that the manufactured product fulfills the customers requirements. The process improvement and implementation of new technology that help reduce the processing time of the product are generated by conducting brainstorming sessions and kaizen. The time reduction between stations will also help to reduce the processing time of the product and provide a clear path for JIT implementation. [23] Implementation of JIT methods often begins in an assembly department with the introduction of kanban. Only when the implementation

program begins in the fabrication areas supplying the assembly department do the most serious problems with JIT arise. The farther back in the supply chain JIT is implemented, the harder problems become, especially in the management of outside suppliers such as foundries where economics still requires the batching of jobs. The results were positive and suggest a need for creativity in JIT implementation rather than strict adherence to a cookbook approach.

#### 4. Conclusion

The main objective of this paper is to implement the JIT in a foundry using inventory handling and mix model manufacturing. The industry is facing some customer complaints related to delays in delivering the products that are ordered, and because of that, a full analysis is done in the foundry to find out the problems that are root cause for the above-mentioned problem. For finding out the problems X matrix and VSM are used. The key areas that are needed to be improved are found from the analysis and suitable lean tools are used to reduce these problems. For further improvement in the manufacturing process of the foundry, an automated system needed to be developed, major time consumption time in the foundry is the pattern and core-making processes to reduce the time Virtual Reality (VR) / Argument Reality (AR) and advanced 3D printing technology can be used. The results that are arrived from the study are,

- Based on the predicted future demand the raw material inventory is maintained. This will reduce the inventory size and the cost of buying the raw material will also get reduced.
- ABC inventory handling implementation helps to organize the finished goods inventory based on their values. The information gained from the analysis reduces obsolete inventory and can boost the inventory turnover rate, or how often a business has to replace items after selling through them.
- The layout of the industry is slightly modified for the implementation of Mix Model Manufacturing, this will help in producing products with variants without altering the manufacturing process.
- The WIP inventory is also reduced by the implementation process improvement in the knockout operation and pull system. By reducing the WIP inventory the processing time is also getting reduced.

The prediction of future demand will also help to produce the product in advance and this helps in delivering the product to the customer in less time.

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