# Productivity Improvement by Value Stream Mapping in Die Casting Industry

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***Abstract*: *Value Stream Mapping has the reputation of uncovering waste in manufacturing, production and business processes by identifying and removing or streamlining non-value-adding steps. A flow diagram showing the process is drawn to reflect the current state of the operation. The non-value actions are identified in each step and between each step by their waste of time and resources. The process is analyzed with the help of simulation software for opportunity to drastically reduce and simplify it to the fewest actions necessary. By reducing wastefulness the proportion of value adding time in the whole process rises and the process throughput speed is increased. This makes the redesigned process more effective (the right things are being done) and more efficient (needing fewer resources). This paper explains about the corrective methods for eliminating the non-value added activities in the die casting industry with the help of Arena simulation software. The reengineered process is flow charted in its future state with process steps and information flows redesigned, simplified and made less expensive and increase in productivity.***

***Key words*: Value Stream, Current Stream Mapping, Future State Mapping, Takt time, Cycle Time, Lean Manufacturing, Simulation.**

## INTRODUCTION

A value stream map is an end-to-end collection of processes/activities that creates value for the customer. A value stream is all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product: (a) the production flow from raw material into the hands of the customer, and (b) the design flow from concept to launch. Standard terminology, symbols, and improvement methods allows VSM to be used as a communication tool for both internal communication and sharing techniques and results with the larger lean community [1].

The increasing intensity of competition in the global market, forcing manufacturers to develop production systems and processes that will provide more flexibility, competitiveness and high quality products and ensure reduction of production costs. At the same time, manufacturers have to pay more attention to product variety and customer value, because era of mass production is over [2].

Value-stream mapping can be a communication tool, a business planning tool, and a tool to manage company change process. Creating a value stream map will allow the company to document current production lead time, inventory levels, and cycle times in order to determine the ratio of value-added to total lead time of the product family being analyzed, creating a vision of an ideal value flow. The focus of the approach is on cost reduction through eliminating non value added activities via applying a management philosophy which focused on identifying and eliminating waste from each step in the production chain respective of energy, time, motion and resources alike throughout a product's value stream, known as lean. [3].

## LITERATURE REVIEW

Hugh L. McManus and Richard L. Millard explored the concept of Value Stream Analysis and Mapping (VSA/M) as applied to Product Development (PD) efforts. Value Stream Analysis and Mapping is a method of business process improvement. The application of VSA/M began in the manufacturing community. PD efforts provide a different setting for the use of VSA/M. Site visits were made to nine major U.S. aerospace organizations [4].

Mahmoud Al-Odeh et al. suggested that VSM can identify continued opportunities to enhance value, eliminate waste, and improve flow. It is known that VSM can identify continued opportunities to enhance value, eliminate waste, and improve flow. In this work, four steps were followed while implementing VSM: identifying the product, creating a current state value stream map, creating a future state value stream map, and creating an action plan. Takt time, process cycle time, and process cycle efficiency (PCE) were computed for prior and post states for comparison. Although PCE did not improve, takt time, cycle time, budget, and number of required employees were significantly reduced [5].

Palak P. Sheth1 et al. suggested that Value Stream mapping aim is identified waste in terms of non-value added activities. Current State Map is prepared to give details about the existing position and identify various problem areas. Future State Map is made to show the implementation action plan. Value Stream Mapping is visualization and streamlines work processes using the tools and techniques of Lean Manufacturing. VSM help to identify demonstrate and decrease waste in the processes. Waste being any activity that does not add value to the final- product. VSM can serve as a blue print for Lean Manufacturing [6].

Rehab M. et al. suggested that increasing volatility, global competitiveness and sales crisis as all force the manufactures to the journey of world class manufacturing performance via adopting "Lean System" to enable economic success in difficult times. Among the journey to lean, one of the hardest steps is measuring the properties of lean policies implementation especially in this highly dynamic market. This paper presents a dynamic model to evaluate the degree of leanness in manufacturing firms. The model is based on system dynamic approach and presents a "leanness score" for the manufacturing system. In addition, it examines the dynamics associated with the application of "one-piece flow" concept via "Takt Time". Results show that working on adjusting the system's cycle times to follow Takt Time will improve the overall performance [7].

## PROBLEM DEFINITION

Being a company that is driven to always meet their customer's demands and the nature of the market can affect the product realization process. These companies need improvement in the productivity in their product realization process as well as in the product designs.

This is the existing situation at Company XYZ which has led to a yearly trend of reduced defects, an increased product range demand, and production of customized orders. This puts pressure on the production system to be efficient and flexible. The Problem in this company is increased cycle time made the company not to produce the desired product to satisfy the customer needs due to non-value added activities in the value stream. Company's strategy to always meet their customer's functional demands or customized requirements induces high pressure on the product development function, dealing with both customized orders, and development of new products to meet the market's needs.

## RESEARCH METHODOLOGY

To start improving productivity by identifying waste and then removing it by implementing lean principle in the industry there is no other tool better than VSM. The Value Stream Mapping method (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process. A manufacturing system operates with timing of step-by step activities. The various steps in implementation of VSM are shown in Figure.6, and are discussed in the following sections. Figure below shows the VSM methodology that was used. It starts with gathering relevant literature on the subject. The product family was then identified. The current state map was drawn for the product. Data for drawing the current state map was gathered through site visits, motion studies, observation, interviews and document review. The current map was then used to identify problems and possible improvements [8].

Before applying VSM methodology, study of whole plant is required with plant manager, supervisors, operators and conducting interviews with these people will help to identify the critical shop floor where we can create the opportunity to improve the productivity. The Company has main divisions namely Design, Foundry, Machining (CAM/CNC) & Assembly. After the discussion with company employees it came to know that foundry shop floor is having so many problems related to cycle time, improper handling of equipments by operators, and wastages of material. Hence the further decision is made to select foundry as critical shop floor and applied methodology as shown in figure 1.

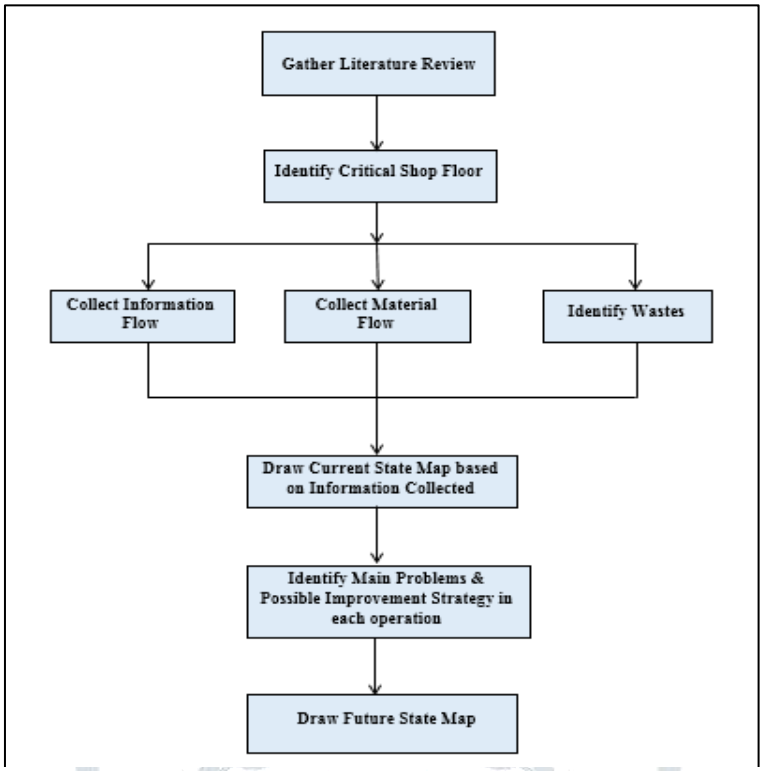



**Figure 1. Value Stream Mapping Methodology**

## VALUE STREAM MAPPING TOOLS

The typology of the seven new tools is presented in terms of the seven wastes already described. In addition the delineating of the overall combined value stream structure will be useful and will also be combined as shown in the table 5. Until now, however, there has been no decision support mechanism to help choose the most appropriate tool or tools to use. The tools themselves are drawn from a variety of origins as show below. These origins include engineering (tools 1 and 5), action research/logistics (tools 2 and 6) operations management (tool 3), and two that are new (tools 4 and 7). As can be seen, they are generally from specific functional ghettos and so the full range of tools will not be familiar to many researchers, although specific tools may be well-known to individual readers. Each of these is reviewed in turn before a discussion is undertaken of how they can be selected for use [9]. Table 1 explains about the seven value stream mapping tools and origin of tools.

**Table 1. Seven Value Stream Mapping Tools**

| S.No | Mapping Tools | Origin of Tools |
|---|---|---|
| **1** | Process Activity Mapping | Industrial Engineering |
| **2** | Supply Chain Response Matrix | Time Compression / Logistics |
| **3** | Production Variety Funnel | Operations Management |

| | | |
|---|---|---|
| **4** | Quality Filter Mapping | New Tool |
| **5** | Demand Amplification Mapping | System Dynamics |
| **6** | Decision Point Analysis | Efficient Consumer Response Matrix |
| **7** | Physical Structure Mapping | New Tool |

**INTEGRATION OF VALUE STREAM MAPPING WITH SIMULATION**

Simulation Combined with Value Stream Mapping offers a viable tool for evaluating the potential level of productivity gains which can be achieved using lean concepts. Simulation as a guided tool to assist organizations with decision to implement lean approaches by quantifying benefits from applying the VSM. Simulation is defined as "…the process of designing a model of a real system and conducting experiments…" and "A simulation is a model that mimics reality". Simulation has played an important role in the industrial development in recent years, at least within companies in the Western part of the world.

New ways to use simulation and improved technologies are continuously being developed which improves the usefulness of simulation. During the course of this research a tool for Simulation Based Value Stream Mapping (SBVSM) has been developed. The tool is aimed at being able to construct dynamic values stream maps that could represent the snapshot picture at any time during a time period and not only at one specific time, as normal VSM's do [10]. A road map is provided to illustrate how the VSM is used to design a desired future state. A simulation model is developed to replicate of an existing system and that of proposed system that modifies the existing design to incorporate lean manufacturing shop floor principles [11].
After the initial step of the mapping the current state, the work flow is divided simulation & VSM are carried out in parallel as shown in figure 2. To build simulation model data can be collected by observations, interviews, workshops or archival documentation. Simulation model developed is verified by tracing entities to determine if the model's relationships are correct and accurate. During verification, the performance of the simulation model is compared with existing system. If the results are optimum then only the implementation of new ides applies in the existing system. This improvement process is never ending process so kaizen word is specified in the figure 2.which shows that implementing new ideas to the existing system for continuous improvement in the productivity.

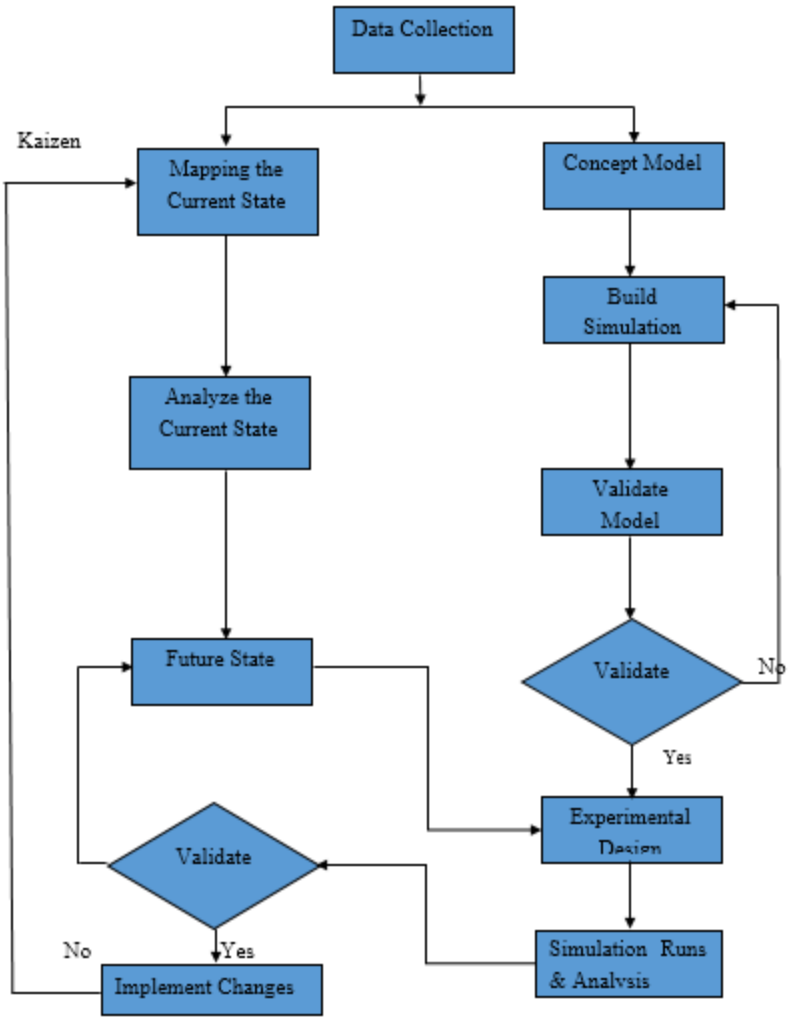



**Figure 2. Integration of Value Stream Mapping with Simulation**

The Validation of the simulation model through visualization enables the simulators & managers to walk through the virtual environment step by step to determine whether the simulation model behaves as determined by future state map. If the problems are identified, the process returns to the step building simulation model, at the same time the VSM helps to identify difficulties from current state map & remove them (i.e non-value added activities), generating future state map. The VSM & simulation work flows are merged at the experimental design step integrating static and dynamic simulation to produce hard facts about proposed changes. Simulation is used to evaluate & validate the expected out comes of the different scenarios, if the outcomes are desired then the future VSM is implemented in order to increase productivity [12].

**ARENA SIMULATION MODELING**

Arena Basic Edition software lets you bring the power of modeling and simulation to business process improvement. It is designed primarily for newcomers to simulation and Serves as an introductory product and foundation to the rest of the Arena product family. Typically, any process that can be described by means of a flowchart can be simulated with Arena Basic Edition.

## DATA COLLECTION METHODOLOGY

- **Site Visits**
  In order to collect the required amount of information (process logic and resource process time) for the proposed allocation system, four visit days were conducted. These visits were divided into day and night visits in order to capture the process flow and to identify the production life cycle at each working shift, see figure 3 for more details about the site visits.

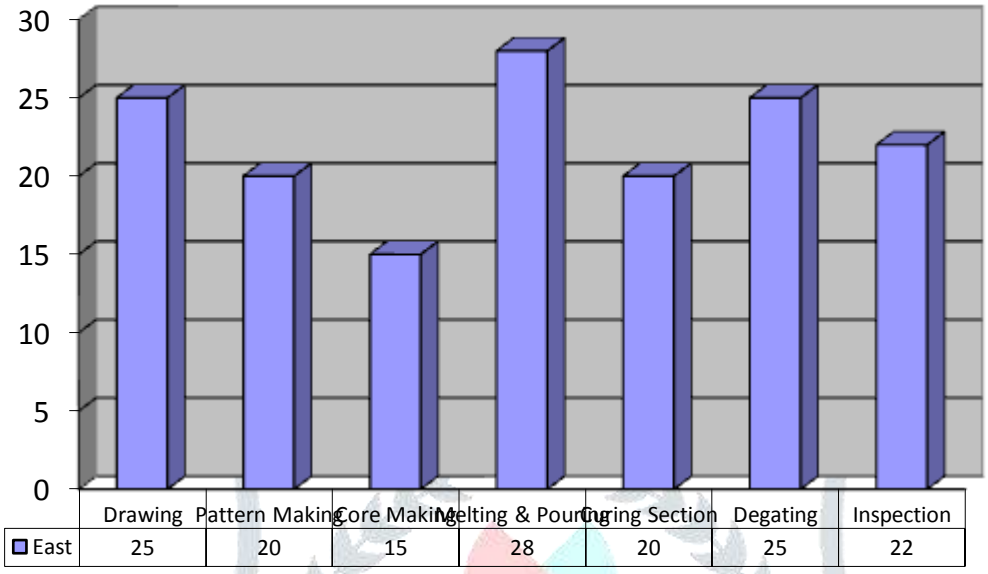



**Figure 3 Site Visits**

- **Structured Interviews:** The structured interview technique as shown in figure 4 approach was chosen in order to collect the required data and a data collection instrument was designed in the form of document containing a number of questions divided into three categories. These categories: identified the problem, data collection, and suggested improvements and solutions. The required level of information, all logical relationships between process and the process detail at each production section were obtained during these interviews. The senior production charge hand was interviewed to understand the logic of a number of production processes. The structured interviews were designed starting with more general questions about the manufacturing system and relationship between production processes and then more detailed questions, regarding process details. The structured interview times were varied depending on the skills and the amount of knowledge which the personal had.

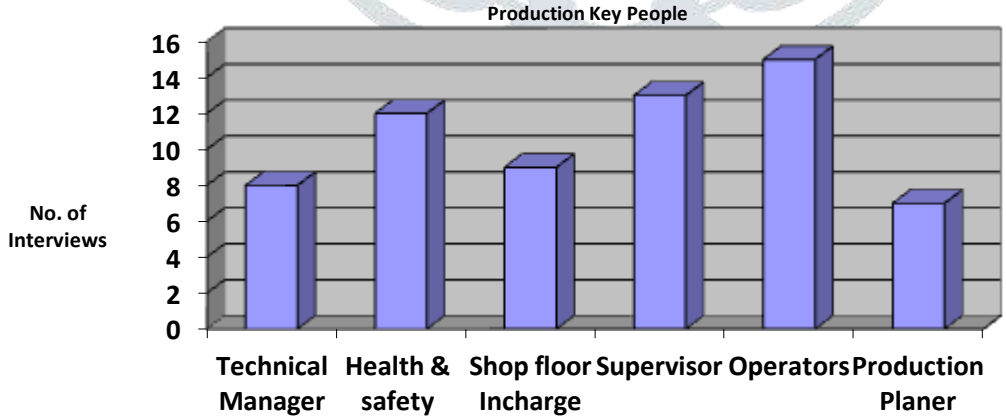



**Figure 4. Structured Interviews**

**IMPLEMENTATION OF VSM IN DIE CASTING INDUSTRY**

XYZ is an aluminum die casting company which produce high quality aluminum die casting components for automotive as well as non-automotive applications. After deciding the foundry as critical shop floor VSM methodology is applied, as per the its steps gathering data related to foundry and prepared Conceptual model which clearly indicates the process flow of raw material to end product in foundry. The main aim of this study is to find out the non-value added activities in this industry using visualization tool as Value stream mapping and taking the corrective action on those activities which are really reducing the productivity using lean techniques and simulation software. The detailed explanation in this chapter about the value added and non-value added activities in this industry and suitable method to eliminate them.

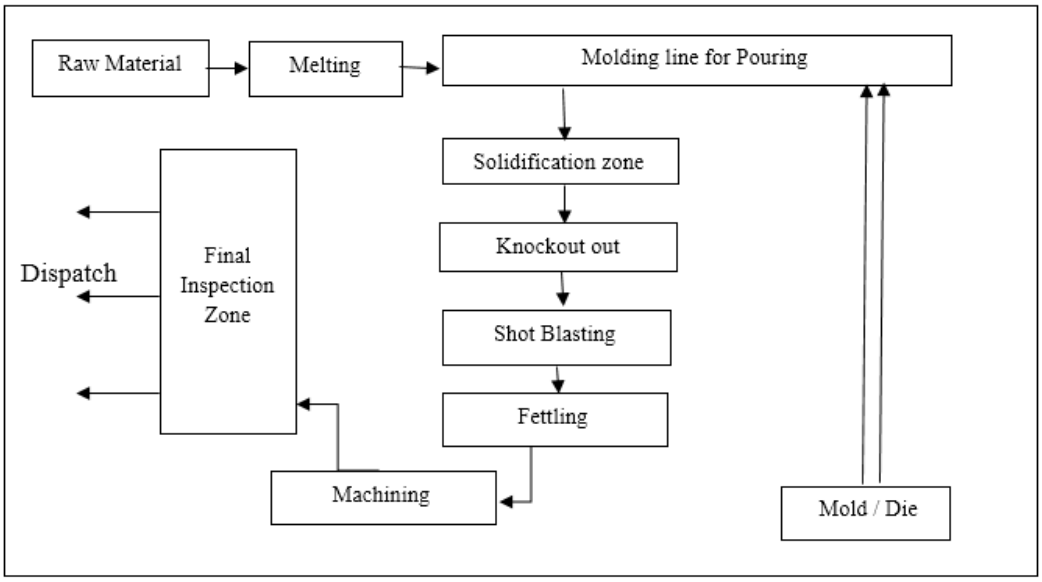



**Figure 5 Current Foundry Production Lay out**

Current foundry lay out of the industry where raw material to cast product by passing through different work stations as shown in figure 5. Raw material is heated to higher temperature to convert it in to molten metal, dies (permanent molds) are cleaned properly by manually and send it to pouring section where molten metal poured in to dies, molten metal reaches in to the mold space due to gravity. Once die is filled then it has to send it for solidification, dies cooled with external environment, after solidification knocking process takes place in which separation of casting from molds, then separated castings sent to shot blasting where strengthening of products with heat treatment takes place, after heat treatment casting are sent to fettling process where cleaning of casting like extra protrusions, marks etc. once fettling is over castings are sent in to machining process to achieve required dimensions, then finally after inspection, castings are dispatched to warehouse.

Data will be collected in both day and night shifts, day shift starts at 9 am to 5 pm & night shift starts at 6 pm to 2 am. And second type is based upon workers experience it can be classified as semi-skilled, skilled and Multi-skilled workers. Based upon the shifts cycle time of production collected is shown in table 2. And Figure 6 indicates the current state map of the industry.

**Table 2 .Cycle time of Pivot Housing**

| S.NO | Products | Pivot Housing | | Number of Operators |
|---|---|---|---|---|
| | Steps | Day Shift | Night Shift | |
| **1** | Cleaning of Dies | 10 | 15 | 2 |
| **2** | Pouring Molten Metal | 2 | 3.5 | 2 |
| **3** | Knockout | 1.5 | 1.9 | 2 |
| **4** | Shot Blasting | 5 | 4 | 1 |
| **5** | Fettling | 15 | 16 | 1 |

| | | | | |
|---|---|---|---|---|
| **6** | Inspection & Oil Dip | 3.08 | 3.45 | 1 |
| **7** | Machining | 2.5 | 3.2 | 1 |
| | Total set up time | 26 | 32 | 10 |

**Current State Map**

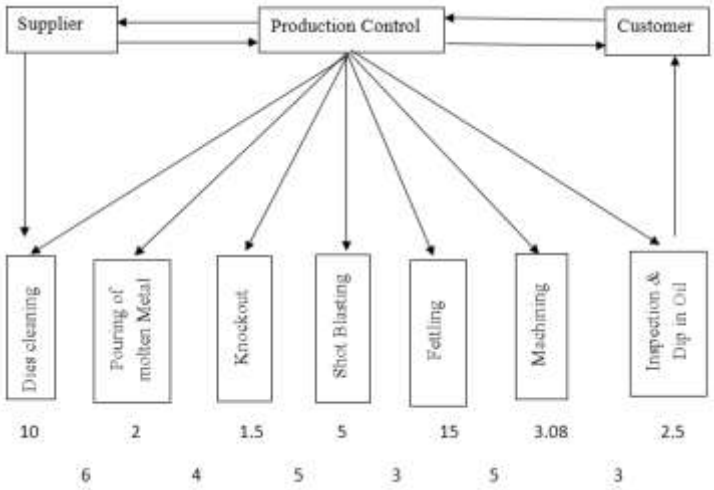



**Figure 6. Current State Map**

From the Current Situation of the industry following observations are made and figure 6 shows the current state map of the industry.

- Working Shifts per day: 2.
- Number of work stations: 7.
- Total Available Time for production: 2X8 = 16 hrs =960 min.
- Lunch break for each shift is = 30 min so
- Total available time for production per day = 900 min.
- But actual production of products per day =**14** (65.08 min per product)
- Total Working days of the industry in a month: 26.
- Total production rate per month: 26X14 =**364** products per month.

Customer demand per month: **430** products.

- Total Value Added Time for Production: 39.08 min per part.
- Total non-value added time for production: 26 min per part.
- Total production Time: 65.08 min per part.
- Total available time for production: 480-30= 450 min per shift.
- Takt Time = Total Available Time for production / Customer Demand.

= 23400/430 = **54** min per product.

**Arena Simulation Model for Current State Map**

Based on the current state map information, the process flow of the die casting industry is fed in to the Arena Simulation Software, creating the model as shown in figure 7 and simulation is carried out using Current state model then the results obtained from the simulation software indicates the Value added as well as non-value added activities those results are obtained.

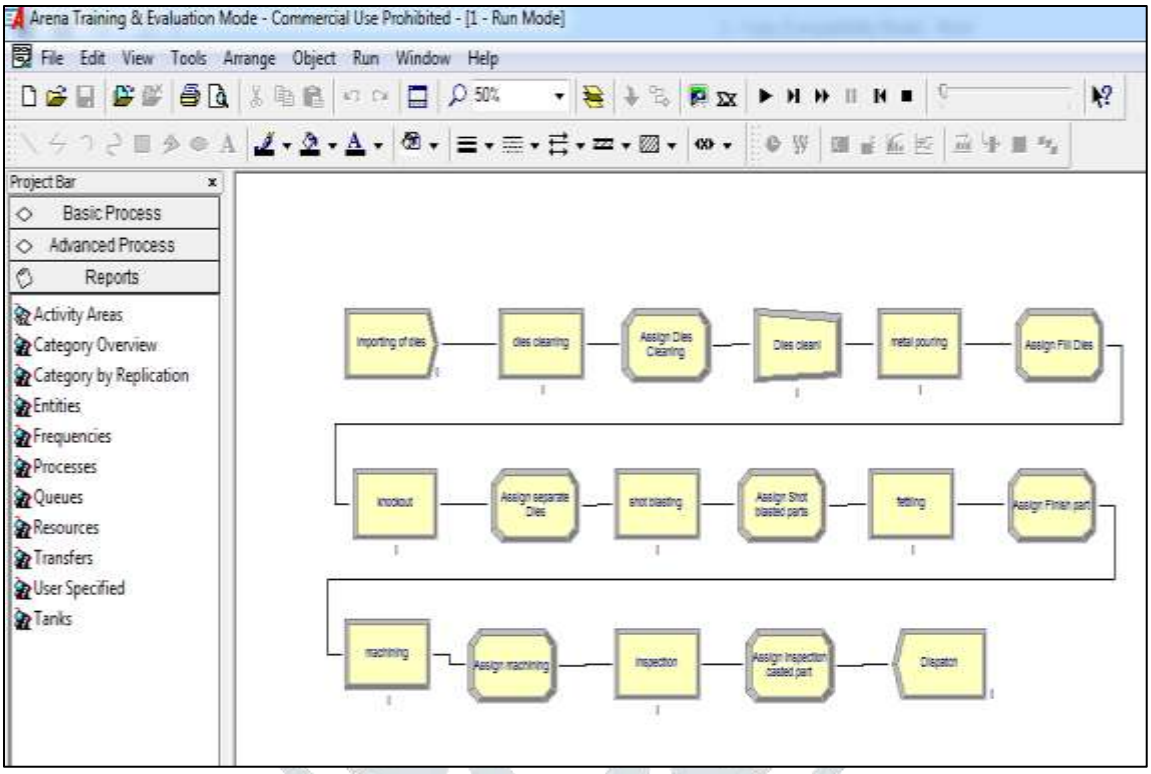



**Figure 7. Arena Simulation Model for Current State Map**

Figure 8 shows Simulation Results Based on Current State map: By analyzing the Current State Map simulation results are obtained.

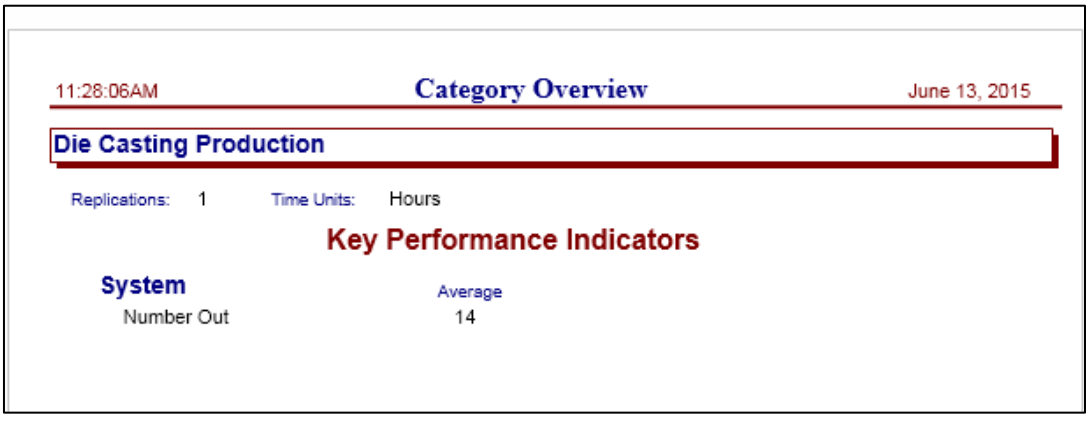


**Figure 8. Key Performance Indicator**

11:28:06AM **Category Overview** June 13, 2015

**Die Casting Production**

Replications: 1 Time Units: Hours

**Queue**

**Time**

| Waiting Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Dies cleaning .Queue | 0.00 | 0.00 | 0.00 |

**Other**

| Number Waiting | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Shot Blasting Queue | 0.02 | 0.00 | 1.0000 |
| Fettling Queue | 0.025 | 0.00 | 1.0000 |
| Machining Queues | 0.025 | 0.00 | 1.0000 |

**Figure 9 Category Overview of Queue**

3:28:06PM **Category Overview** June 14, 2015

**Die Casting Production**

Replications: 1 Time Units: Hours

**Entity**

**Time**

| VA Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.6513 | 0.63000 | 0.6513 |

| NVA Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.300 | 0.00 | 1.00 |

| Wait Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.100 | 0.00 | 1.00 |

| Transfer Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.0300 | 0.00 | 1.00 |

| Other Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.00 | 0.00 | 0.00 |

| Total Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| cast product | 1.08400 | 1.035000 | 1.08800 |

**Other**

**Figure 10 Category Review of Time Entity**

Figure 8 indicates quantities of output products from the industry per day. All the Values in the figures 9 and 10 are in hours and those Values indicate that Value added time for production is 0.6 hours (39.08 min), non-value added activity 0.2 hours (12 min), Waiting time 0.01 hours (0.6 min), transfer of products 0.1500 (9 min). From the above results we can judge the reason for decreasing

the productivity or increasing in cycle time. Total Value Added Time for Production: **60.04%.**Total Non-Value Added Time for Production: **39.96%** (It includes non-value added activities like waiting, unnecessary transportation, over production etc).

**CORRECTIVE ACTION FOR IMPROVEMENT**

From the above simulation result discussion it is observed that about 39.96% non-value added activities are present in Stream line of die casting industry, in this non-value added activities some activities are necessary but they won't add the value to the streamline. And some non-value added activities are unnecessary those activities should be eliminated. Value Stream Mapping is visualization tool through which we identified where non-value added activities are present, now with the help of lean techniques we can reduce the non-value added activities.

**Kaizen**

Kaizen means improvement, continuous improvement involving everyone in the organization from top management, to managers then to supervisors, and to workers. In Japan, the concept of Kaizen is so deeply engrained in the minds of both managers and workers that they often do not even realize they are thinking Kaizen as a customer-driven strategy for improvement**.** This philosophy assumes according Imai that ''our way of life – be it our working life, our social life or our home life – deserves to be constantly improved''. the meaning of the Japanese words 'Kai' and 'Zen', which translate roughly into 'to break apart and investigate' and 'to improve upon the existing situation'. Improvement begins with the admission that every organization has problems, which provide opportunities for change. It evolves around continuous improvement involving everyone in the organization.

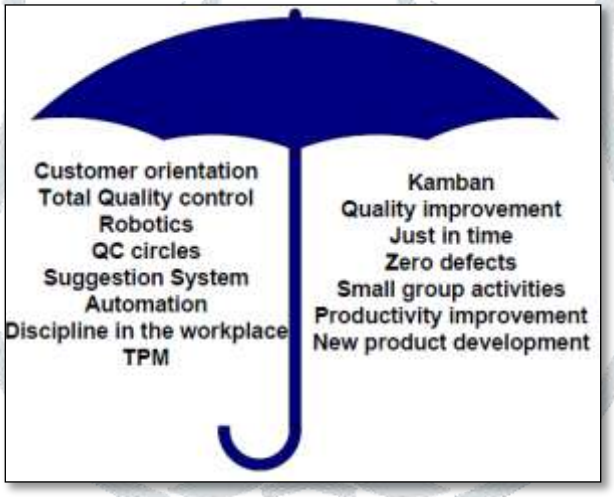



**Figure 11 Kaizen Umbrella**

The figure 11 shows that the common aim of both Value Stream Mapping and Kaizen, that is to improve the productivity. So this philosophy is used in die casting industry to improve the productivity.

**Important Steps taken in industry to implement Kaizen**

As we know that casting industry environment is full of dirt and smoke. So first preference is to improve the work environment for the employees to will them to work with maximum efficiency. So housekeeping is first necessary action to be made.For proper housekeeping a valuable tool or methodology is used, the 5S methodology. The term "Five S" is derived from the first letters of Japanese words referred to five practices leading to a clean and manageable work area: seiri (organization), seiton (tidiness), seiso(purity), seiketsu (cleanliness), and shitsuke (discipline). The English words equivalent of the 5S's are sort, straighten, sweep, sanitize, and sustain. 5S evaluations provide measurable insight into the orderliness of a work area and there are checklists for manufacturing and nonmanufacturing areas that cover an array of criteria as i.e. cleanliness, safety, and ergonomics.

From the current state map Non-value added activities are namely waiting and for this Muda of waiting occurs when the hands of the operator are idle; when an operator's work is put on hold because of line imbalances, a lack of parts, or machine downtime; or when the operator is simply monitoring a machine as the machine performs a value-adding job. Watching the machine, and waiting for parts to arrive, are both muda and waste seconds and minutes. Muda elimination in this area presents a golden opportunity for Kaizen. The operators are semiskilled in the company so as to improve the skill training is needed.

**ARENA SIMULATION MODEL FOR FUTURE STATE**

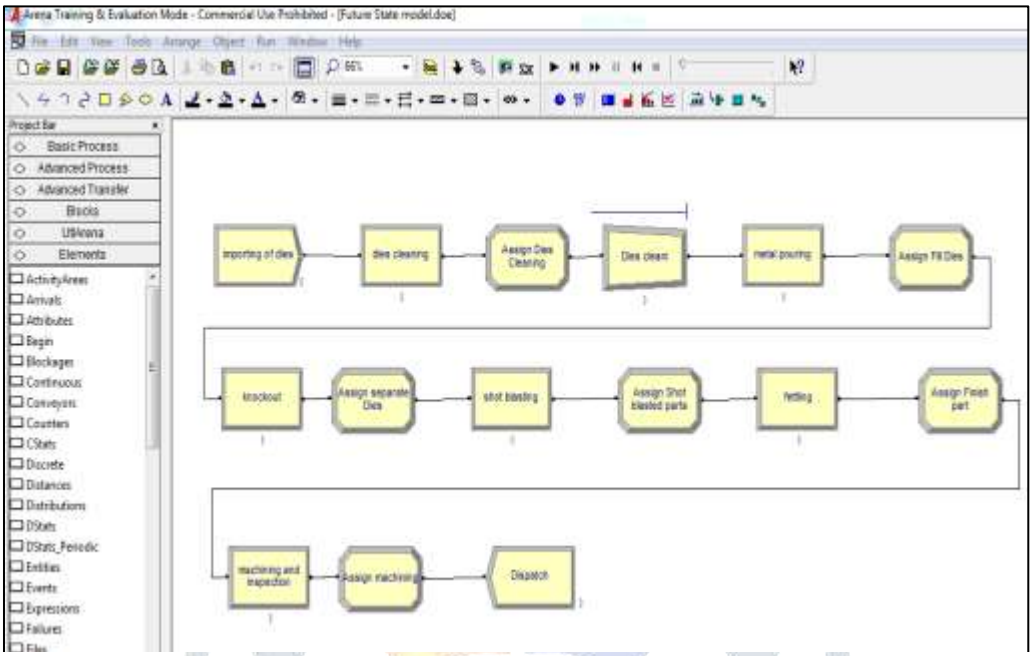
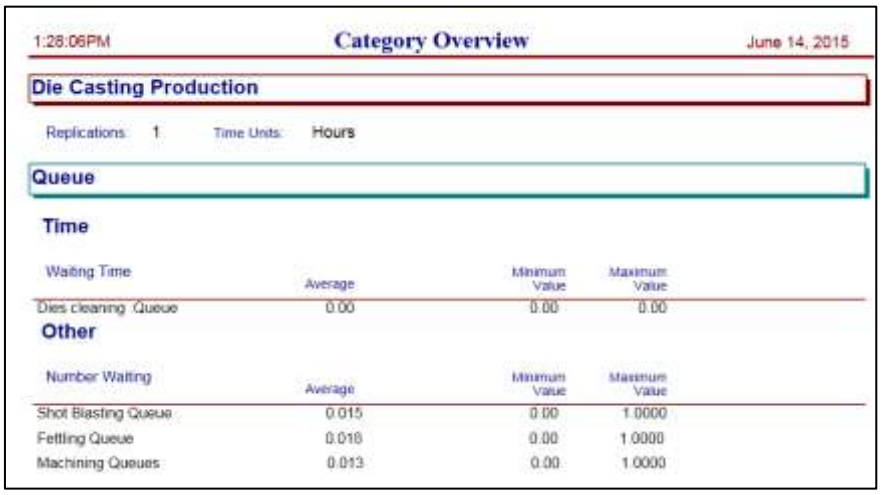



**Figure 12 Arena Simulation Model**

Figure 12 shows future state simulation model from the corrective action taken which is discussed above section, future state simulation model is build and necessary changes are made in the current state map and after running simulation model the following results obtained.


1:28:06PM Category Overview June 14, 2015

Die Casting Production

Replications: 1 Time Units: Hours

Queue

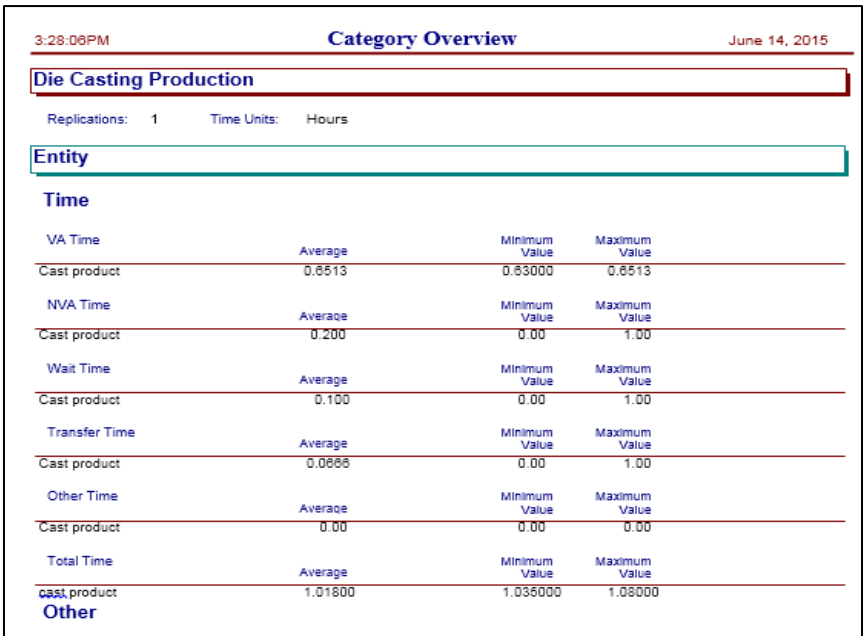
Time

| Waiting Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Dies cleaning Queue | 0.00 | 0.00 | 0.00 |

Other

| Number Waiting | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Shot Blasting Queue | 0.015 | 0.00 | 1.0000 |
| Fettling Queue | 0.018 | 0.00 | 1.0000 |
| Machining Queues | 0.013 | 0.00 | 1.0000 |

**Figure 13. Category Review of non-value added activities**


3:28:06PM Category Overview June 14, 2015

Die Casting Production

Replications: 1 Time Units: Hours

Entity

Time

| VA Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.6513 | 0.63000 | 0.6513 |

| NVA Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.200 | 0.00 | 1.00 |

| Wait Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.100 | 0.00 | 1.00 |

| Transfer Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.0666 | 0.00 | 1.00 |

| Other Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| Cast product | 0.00 | 0.00 | 0.00 |

| Total Time | Average | Minimum Value | Maximum Value |
|---|---|---|---|
| cast product | 1.01800 | 1.036000 | 1.08000 |

Other

**Figure 14. Category Overview of Product Entity**

Figure 13 indicates about the non-value added activity times in the value stream and these results are due to corrective action taken in the system. Figure 14 indicates the overview of the product entity.

**RESULT & DISCUSSION**

From the simulation analysis the following improvements are observed:

- Reduction in total Cycle time for the production is 6.146%.
- Reduction in in non-value added activities from 39.96 % to 24.57% (15 % of NVA)
- Improvement in labor productivity and work environment by Kaizen philosophy.
- Hence Productivity improved due to reduction in cycle time and non-value added activities.

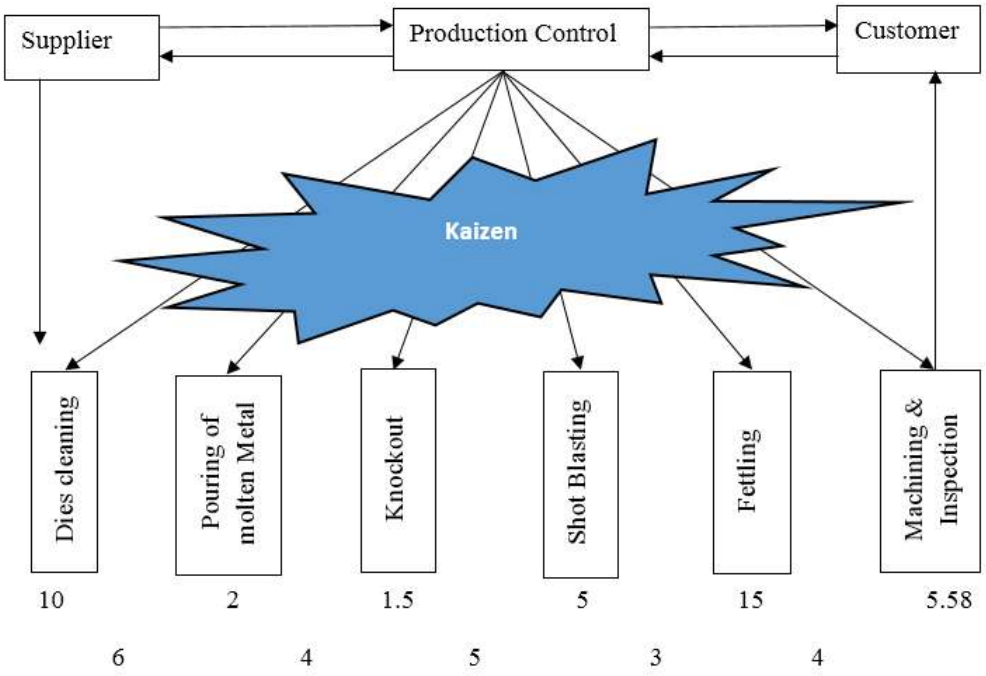



Figure 15 Future State Map

From the figure 15 shows Future State Map and based on that following cycle time obtained

- Total Cycle time for Production: 61.08 min per part.
- Total value added time for Production: 39.08 min per part.
- Total non-value added time for Production: 22 min per part.

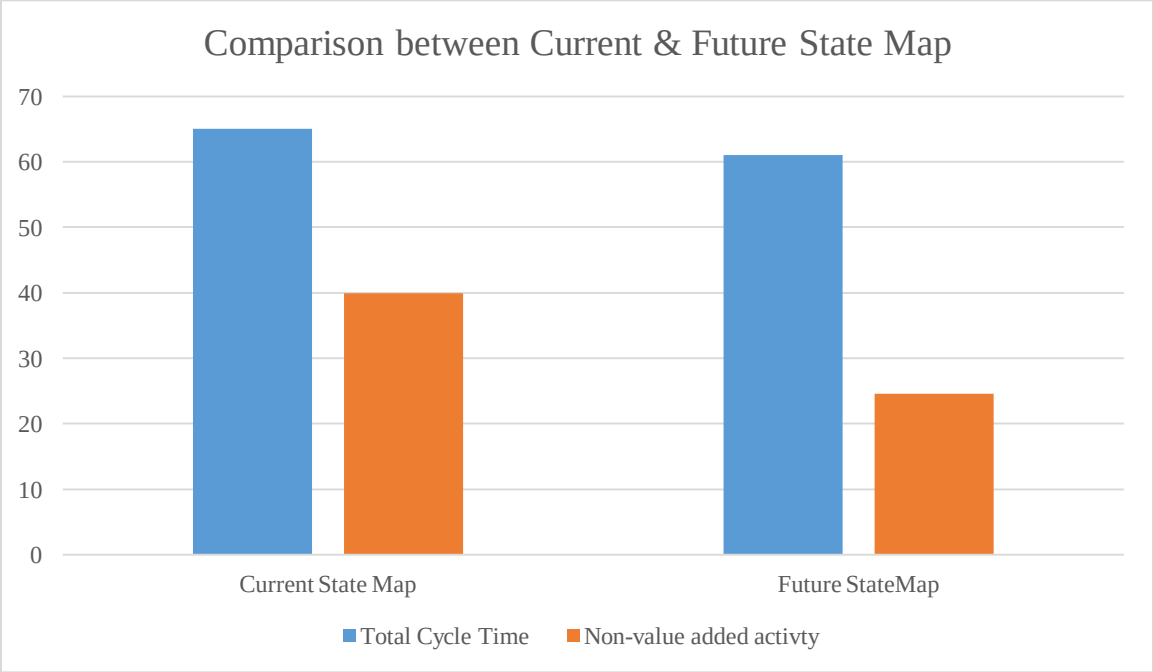



Figure 16 **Comparison between Current & Future State Map**

Figure 16 explains the result comparison between current State total cycle time and future state cycle time for production. And percentage comparison between non-values added activities in current and future state.

**Conclusion**

Value stream mapping tool can be used effectively in any kind of sectors as it is a world class manufacturing tool. The analyzed study is case study in die cast industry. The prime objective is to elimination of waste in a value stream. In this study Value Stream Analysis tool is used to identify non-value added activities. 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 15% waste reduction in non-value added activities from the value stream, hence total cycle time is reduced by 6.146%. Integration of VSM with Simulation software will help to analyze the system properly. Value Stream Mapping is visualization tool used to find the opportunity to improve the productivity.

**REFERENCES**

1) R.M. Belokar, Sandeep Singh Kharb, Vikas Kumar "An Application of Value Stream Mapping In Automobile Industry: A Case Study", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Vol.-1(2), pp.231-236, (2012).
2) Muhammad Abdus Samad et.Al, "Value Stream Mapping To Reduce Manufacturing Lead Time In A Semi-Automated Factory", Asian Transactions On Engineering, Vol.2 Issue 06, pp. 22-28, (2013).

3) Danijela Gracanina & BorutBuchmeister, BojanLalic "Using Cost-Time Profile for Value Stream Optimization", Procedia Engineering 69 (2014), p. 1225 – 1231.
4) Rahani AR, Muhammad al-Ashraf "Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study", Procedia Engineering, Vol.41, pp.1727 – 1734, (2012).
5) Mahmoud Al-Odeh et.al, "Value Stream Mapping: Recreating an Industrial Environment in an Educational Setting", Proceedings of The (2014) IAJC/ISAM Joint International Conference ISBN, p.978-1-60643-379-9.
6) Palak P. Sheth1 et.Al, "Value Stream Mapping: A Case Study of Automotive Industry", Ijret (2014), p.2321-7308.
7) Rehab M. Ali et.al "Dynamic Lean Assessment for Takt Time Implementation", Procedia CRIP 17 (2014), p.577-581.
8) G. M. Gohane, A. S. Bonde & C.S. Sable," Improvement of Productivity Using Value Stream Mapping", IJSRD - International Jour nal for Scientifi c Research & Development| Vol. 2(8), ISSN (online): 2321-0613, pp.1-5, (2015).
9) G. Sahitya Reddy, Harsha Lingareddy & K.Jagadeeshwar, "Value Stream Mapping In A Manufacturing Industry", International Journal of Advanced Engineering Technology E-ISSN 0976-3945, Vol.4(2), pp.20-23,(2013).
10) Binu Bose V & K N Anilkumar, "Reducing rejection rate of castings using Simulation Model", Proceedings of International Conference on Energy and Environment, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2(1), pp.589-597,(2013).
11) Petter Solding & Per Gullandar, "Concepts for Simulation Based Value Stream Mapping", Proceedings of the 2009 Winter Simulation Conference, pp.2231-2237, (2009).
12) Wei Xia & Jiwen Sun, "Simulation guided value stream mapping and lean improvement:A case study of a tubular machining facility", Journal of Industrial Engineering and Management, JIEM,pp.456-476, (2013).
13) Abu Md. Saifuddoha, Md. Ahasan Habib2, Sohana Yasmin Sumi, Md. Jennurine, Md. Saiful Islam, "Minimization Of Waste By Applying Value Stream Mapping In The Supply Chain Of Cement Industry", IOSR Journal of Business and Management (IOSR-JBM), ISSN: 2319-7668, Volume 9, Issue 3,pp.79-84,(2013).
14) S. Santhosh kumar, M. Pradeep kumar, "Cycle Time Reduction of truck body assembly in an automobile industry by lean principles", Procedia Materials science, Vol.5, pp.1853-1862, (2014).
15) Schönemann, M. et.al "Integrating product characteristics into extended value stream modeling", Procedia CIRP (2014) p.368 – 373.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