This paper attempts to integrate Value Stream Map (VSM) with the cost aspects. A value stream map provides a blueprint for implementing lean manufacturing concepts by illustrating information and materials flow in a value stream. The objective of the present work is to integrate the various cost aspects. The idea is to introduce a cost line, which enhances the clarity in decision making. The redesigned map proves to be effective in highlighting the improvement areas, in terms of quantitative data. TAKT time calculation is carried out to set the pace of production. Target cost is set as a benchmark for product cost. The results of the study indicate that implementing VSM led to reduction in the following areas: processing lead time by 34%, processing cycle time was reduced by 35%, inventory level by 66% and product cost from Rs 137 to Rs 125. It was found that adopting VSM in a small scale industry can make significant improvements.

1. Introduction
Success in modern manufacturing industry directly correlates to how a company handles global competition. Cost effective solutions and practices are essential to stay competitive in the market. Many manufacturing facilities have experienced the drastic changes and are in a process of undergoing physical and cultural transformation to adopt the concept of lean thinking. Lean has been originally created and defined as the process of eliminating waste (Womack et al. 1990) Toyota along with the support of a system to reduce or eliminate waste and non-value added activities from the various process (Ohno, 1988; Shingo and Dillon, 1988).
The conceptual framework for categorizing all of the tools and practices of lean production in five basic areas:

- **Value**: Define value from the standpoint of the customer. However, in reality, the final customer is the only one who can specify the value of a specific product or service by paying a price for it.

- **Value stream**: View your product delivery system as a continuous flow of processes that add value to the product.

- **Flow**: The product should constantly be moving through the value stream towards the customer at the pace of demand.

- **Pull**: Product should be pulled through the value stream at the customer’s demand rather than being pushed on to the customer

- **Perfection**: The never-ending pursuit of eliminating waste in the system such that the products can flow seamlessly through the value stream at the rate of demand.

2. Literature Survey

VSM can serve as a good starting point for any enterprise that wants to be lean and describe value stream as a collection of all value added and non-value added activities which are required to bring a product or a group of products using the same resources through the main flows, from raw material to the hands of customers (Chandandeep, 2006).

Researchers define the VSM as the process of visually mapping the flow of information and material. It helps to visualize the station cycle times, inventory at each stage, manpower and information flow across the supply chain (Womack and Jones, 1996). A value stream map provides a blueprint for implementing lean manufacturing concepts by illustration how the flow of information and materials should operate.

Balkema and Rotterdam (2004) have created current state map for a steel producer, a steel service center and first-tier component supplier. The current state map identifies huge piled of inventory and long lead-time. In the future state map target areas were subjected to different lean tools including kanban, supermarket, and continuous flow.

Ballard and Howell (1994) suggest that, the value stream mapping can serve as a good starting point for any enterprise that wants to be lean. It provides a common language for
talking about manufacturing process. It ties together lean concepts and techniques which help to avoid "cherry picking". It forms the basis for an implementation plan by helping to design the whole flow. Halpan and Kueckmann (2001) explain value stream mapping in aircraft manufacturing. They draw current and future state maps were developed with the objective of reducing lead time according to customer requirements. The implementation of the future state map attained lead-time reduction. Summer, 1998 has described Activity Based Costing (ABC), identify various cost components and analyze the relative contribution to the total cost. The essence of ABC is that, product consumes activity, activity consumes resource and resources generate cost. Thus it is necessary to develop the relationship between activity, cost drivers and activity measures. Target costing is to anticipate the acceptable market price through intensive customer focus. Design and manufacturing team’s allies to bring the product within the target cost. Target cost is the cost that can be incurred while still earning the desired benefit. The objective of the present work is to demonstrate how a manufacturing system operates with timing of step-by-step activities.
3. Methodology

The various steps in implementation of VSM are shown in Figure 1 and are discussed in the following sections. The process analyses is carried out by collecting data from various enquiries with shop floor experts and directly participates in measuring the time involved in various processes (Sahoo et al, 2008).

![Figure 1. Steps in implementing Value Stream Map](image)

The new concept introduced in the author’s research is to map/measure the cost involved in the value stream. The study research led us to involve various costing systems and inventory management systems. A case study of a small motor manufacturing company participated in LEAN project has also been presented. The current and future state drawings are mapped for the shaft manufacturing. Future state maps were developed with the objective of reducing lead time and cost according to customer requirement.

The cost analysis is carried out by adding the essence of activity based costing and target costing. In this paper, while generating the VSM, the main processes are identified and the processing costs are calculated for individual processes, now these individual costs
are the activity cost. The summation of the activity costs gives the manufacturing cost of the product. The calculations of the activity cost are elaborated in methodology.

The concepts of ABC inventory management system is used to classify the handling cost of the work in process inventory. So the classification of the inventory helps us to differentiate the various costs incurred in handling the different work in process between different stations. The redesigned VSM is shown in Figure 2.

![Cost Integrated Value Stream Map](image)

Figure 2. Cost Integrated Value Stream Map

The present study uses the philosophy of target costing to set the target manufacturing cost. Target cost is the cost that can be incurred while still earning the desired profit. The target cost is calculated as follows:

\[
\text{Target cost} = \text{Selling price} - \text{Desired profit}
\]
3.1 Process Analysis

The major activity in the process analysis is to portrait the timeline. The timeline contains both value added and non-value added time and is calculated as follows:

\[ VT_i = CT_i \]  
\[ NVT_i = \frac{WIP_i}{D_i} \]

Processing time = \[ \sum_{i=1}^{n} CT_i \]  
Processing lead time = \[ \sum_{i=1}^{n+1} \frac{WIP_i}{D_d} \]

3.2 Cost Analysis

The idea is to add a cost line along with the existing timeline in VSM. Cost line enables better visualization and also improves the clarity of decision making. While the value added cost is brought out by the summation of the direct cost involved in each process, non value added cost analysis is brought about by classifying the inventory as per the holding cost. The cost calculations are as follows:

Value added Activity cost = \( m_i + CT_i \left( \frac{M_i+L_i}{3600} \right) \).  
\( m_i=0 \) (when no material is added in a activity)  
Nonvalue added activity cost = \( h_i + WIP_i \).  
Customer ready to pay = \[ \sum_{i=1}^{n} m_i + CT_i \left( \frac{M_i+L_i}{3600} \right) \]  
Customer not ready to pay = \[ \sum_{i=1}^{n+1} h_i + WIP_i \]

4. Case Study

A case study conducted at a motor manufacturing company is presented and some of the observations may be useful to the practicing engineers in implementing VSM in small, medium and large enterprises. Much of the earlier work have attempted complementary lean manufacturing tools in large scale industries and have recorded their experiments. Hence, there is a need to implement such a lean tool in small and medium size industries.
4.1 Selection of Critical Product Family

The first step is the selection of the critical part family. After the through study of all part families, one part family was rather preferred over all the product families. The Rotor is main heart of the motor.

4.2 Documentation of Customer Information

Interaction with the manager revealed information regarding customer’s requirement. It was understood, the company has a wide range of customers requesting for a wide range of product from 0.5 hp to 20 hp motor. The requirement of motors was estimated to be 1000 motors/month.

4.3 Identification of Main Processes

A quick walk through the shop floor (gemba) helped us in identifying the main processes. The main processes include: bar cutting, roughing, finishing, Threading I, Threading II, key machining and rotor turning.
4.4 Define the Data to be collected

The data in the data box serves to track down the opportunities for improvement. Collection of appropriate data benefits in quick tracking of opportunities. The data box envelopes the following data like cycle time, change over time, up time, machine hour rate, labor hour rate, material cost and the available time. The inventory triangle envelopes two data, work in process inventory between each process and respective handling cost of inventory. Cost and time lines are calculated using the above mentioned model. The current state map is shown in Figure 3.

4.4 Future state map

The objective of the future state map is to match the production rate with TAKT time and to achieve the target cost as the manufacturing cost. Here, for the present study TAKT time is taken as the benchmark for process pace and target cost was set as the benchmark for the manufacturing cost.

4.5 TAKT time: a Benchmark for Process Pace

Takt demonstrates the rate at which the customer buys the product. TAKT reflects the frequency at which the product has to release by the manufacturer to meet customer demands. Takt time is calculated by dividing available working time per shift (in sec) with the customer demand per shift.

\[
TAKT\ Time = \frac{Available\ working\ time\ per\ shift}{Customer\ demand\ per\ shift}
\]

Available working time per shift = Operating time - Breaks

\[= 23280\ seconds/\text{shift}\]

Demand=1000 shafts/month
Demand per shift=40 shafts/shift
TAKT time = 582 seconds/shift

TAKT of 583 represents that, every shaft has to be completed in every 582 seconds. The current state map sights out that the roughing process consumes 18 seconds more than takt time. In order to solve this, finishing and roughing processes are carried out in the CNC machine, thus reducing set-up time and other manual interactions; also the cycle time
of the process is reduced to 120 seconds. The old machine is dedicated to thread cutting operation only. Thus, the total line is balanced.

4.6 Target cost: a Benchmark for Product Cost

Target cost is set by subtracting the market cost by the target profit; the target profit is assigned by the management. The target cost reflects the cost at which the product has to be manufactured. In this case after consulting with the management, the target cost was set at Rs125. Now the lean tools serves as a cost minimization tool to minimize the gap between the Target cost and manufacturing cost.

Daily shipment of bar stock was implemented to reduce the handling cost at the start of the value stream. Single minute exchange of dyes was implemented in the CNC machine (finishing process), in order to minimize the lot/batch size. The future state map is shown in figure 4.

5. Results and Discussions

The implementation of daily shipment resulted in reducing the inventory handling cost from Rs. 30 to Rs. 9, and the inventory is reduced from 100 parts to 30 parts at the start of the value stream. The implementation of SME D serves to reduce the inventory by 66% before the finishing process.
Graphs are employed to visualize the benefits in implementing lean tools as presented in Figure 5-8.

**Figure 5.** Comparisons of cycle time of current and future state

**Figure 6.** Comparison of processing time in seconds

**Figure 7.** Comparison of processing lead time in days
6. Conclusions

This research carries evidence of genuine advantages of applying lean principles in a small scale motor manufacturing. As far as our knowledge is concerned, it is the first time cost analysis is integrated with the value stream map. It was evidenced that VSM is an ideal tool to expose the waste in value stream and identify improvement areas. This paper substantiates the effectiveness of lean principle in a systematic manner with the help of various tools, such as cost analysis in value stream mapping, single minute exchange of dyes and so on. Availability of information such as material and money flow facilitates and validates the decisions to implement lean manufacturing, further would also motivate the organization during the actual implementation in order to obtain the desired benefits. Eventually it enables the companies to move towards their ultimate goal leading to, sustainability, profit and profitability.

7. References


