An Application of Value Stream Mapping in Production Flow Analysis: A Lean Approach in an Automotive Industry

Krushnaraj Bodana, Bimal Kumar Mawandiya, Kaushik M Patel, and Bharat A Modi

Abstract—Lean manufacturing deals with a manufacturing process improvement based on the fundamental goal of Toyota production system in order to eliminate/minimize waste while maximizing the production flow. Today in a highly competitive local and global market, it is very much crucial to satisfy the changing demand of the customers. Thus, in today’s manufacturing industry there is an increased focus to produce the right product at the right time. The prime objective of this research is to apply the lean tool Value Stream Mapping (VSM) to analyze the production flow at an automotive industry and get the benefits through implementation of lean manufacturing. To fulfill the objective of this research, the fundamental principles of lean were implemented and VSM was generated to analyze the production flow at an automotive industry and improve the current state to overcome the difficulties with the current state of work through time study, Takt time calculation and by modifying work cell layout. Further, based on the future state of VSM, final result shows that by implementing this lean techniques, Production Lead-time (PLT) is decreased from 7.6 days to 3.2 days and the cycle time is decreased up to 73%.

Index Terms—Cycle time, Lean Manufacturing, VSM

I. INTRODUCTION

When the issue is about improving productivity, the Japanese philosophy of lean production is a well-reputed and widely used technique. Many of the manufacturing industries that try to become efficient, sooner or later end up with some kind of lean thinking [1]. The use of lean production philosophies as a mean to improve productivity has become increasingly common in western industries. A research in Indian production industry to implement lean manufacturing and analysed the current state of working and ended up with benefits like drastic reduction in lead time, cycle time of the manufacturing operation, change over time and the maximized space utilization. [2]. A lean production applied on Indian machine tool value chains and determined the factors that can have important influence on the performance of the entire value chain and the benefits through VSM was investigated critically for improvement. [3]

Dinesh Seth and Vaibhav Gupta [4] have analyzed the production flow considering broad aspects like Takt time calculations and both existing and proposed states of supplier’s shop floor situations are discussed using value stream methods. At the end, increase in production output per person, reduction of work in process (WIP) and finished goods inventory also accounted and final productivity of the firm reported and shown that VSM is as a method for productivity enhancement at supplier’s end for an automotive industry. Bhim Singh and S.K. Sharma, [5] have shown that how the VSM is supportive in implementation of lean and they have developed the wide horizon in improvements areas to link the shortfall in the current state and the future state of manufacturing industry. The results were clearly indicates the drastic improvement of the firm which are 92.58% decrease in lead time, 2.17% decrease in processing time, 97.1% reduction in WIP and the 26.08% reduction in manpower requirement. Hence, it demonstrate that the VSM can be used before the implementation of lean for better results. Anand Gurumurthy et al. [6] represented that the development of VSM is the first and essential step before the realization of implementation of lean manufacturing. K. Venkataramana et al. [7] have shown that application of VSM is helpful in analyzing the wastes associated with machining center and the same can be reduced by adopting various Kaizens and lean tools for reducing the cycle time of the machining center. S.Vinodh et al.[8] have commented that the intense competition in automobile manufacturing organizations is emphasize to transform their current manufacturing standard to lean manufacturing and they have provided the methodology for the application of VSM in automobile industry. They have also shown that VSM itself suffering from the various shortfalls. However, lean manufacturing implementation faces various challenges in small and medium enterprises (SMEs) [9].

Horacio Soriano-Meier et al. [10] have carried out an interesting research which deals with the impact of the
The main purpose of this research is to apply a lean tool VSM to analyze the production flow at an automotive industry and get the benefits through implementation of lean manufacturing.

III. CASE STUDY
The case study area for the concerns is Product-ABC assembly line in an automotive industry. Assembly of Product-1is consist of four major process 1) Robotic MIG welding process 2) Machining process 3) Coating process and 4) Bush pressing process. Robotic MIG welding is completed across five welding stations. At each of the welding station different sub-parts are welded and proceed further and at the end of the fifth station the weld assembly get completed. Then the machining process required for different machining operations like face milling, drilling, threading and chamfering are completed by two HMCs. Bush pressing operation is performed on the specific designed pressing machine.

Since this company is producing based on the customer’s order, hence its production strategy is based on the concept of takt time. The production line information are as follows:

- Customer demand = 1001 pieces/day ;
- Shifts/day = 3 ;
- Working hours/shift = 8 hours (or) 480 minutes ;
- Break time/shift = 15mins + 30 mins = 45 mins ;
- Net working time/shift = 480 - 45 = 435 mins (or) 26100 secs ;
- Net available time/day = 26100*3 = 78,300 secs ;
- Customer demand/day = 1001 pieces ;
- Takt time = Net available production time / Demand = 78300/1001 = 78 sec/pieces;
- Considering 85 % work efficiency takt time = 0.85*78 = 66 sec/pieces.

But this assembly line has two major concerns. One of them was the higher cycle time in production which leads to insufficient delivery per customer demand and the second one is insufficient use of the available resources such as men, machine and space.

A. The current state:
This section provides a complete picture of the value stream mapping of the company under study which is shown in Fig. 2. The relevant data are collected from the company’s ERP system, from visual observation and by the interviewing of the shop floor operations.

The current state clearly shows that the information related to the product flow, the amount of WIP at each stage of the process, the distance travelled by the materials through the entire process, time required to complete the process at each stage and the amount of value added and non-value added time involved in each process. The current state map also provides a clear overview of the areas in which the improvements are needed and it serves as a base for creating the future state map.

1. Analysing the first process of robotic welding clearly indicates that there is lot of difference in the cycle time of the welded station which supposed to be same as per required cycle time for all the stations indicated by the red coloured line in Fig. 1 to maintain a single piece flow. This difference in cycle times is also the cause of accumulation of inventory between each station as shown in Table I.
2. It is found that the transfer time from one station to next station is also varying for covering the same distance due to manual sort of material handling.

3. In rework station, the cycle time of the rework station is much higher than the required. Further, there is also a large difference in machining cycle time.

4. High time is required for loading, unloading and the transfer before the bush pressing operation.

5. Bush pressing process cycle time itself is high.

6. Inspection process is also a large time consuming hence, it requires more number of operators.

B. Future state VSM:

In this study following improvements were implemented by adopting various lean tools as described in this section:

Assembly line balancing

An assembly line balancing refer as a sharing of total workload of the entire line among each work cells of the line equally due to which idle cycle times remains same station wise and very close to takt time and there should be lowest difference between the cycle time of different stations. The main focus here is to balance the workload of the operators at each station; reduced down the operator’s idle times at stations more than the takt time for reducing the non-value added time at station, which is the outcome of the line balancing and after all which helps in improving the productivity by minimization of the losses. There is clear unbalance of the cycle time of ST-20, ST-40 and ST-50 of the weld line.

The reasons behind this unbalance were carefully observed by using a tool like “time study” shown in Fig. 3. The purpose of performing the time study is to determine the time which an operator should take to perform a specified work at each work cell. The work cell layout were also modified to reduce the time for loading and unloading.

Table 1 : Current state of processing time

<table>
<thead>
<tr>
<th>Stage of process</th>
<th>No. of stations to perform process</th>
<th>Average Cycle time in seconds (Man+Machine)</th>
<th>VA Time in seconds</th>
<th>NVA Time in seconds</th>
<th>VA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotic MIG welding</td>
<td>ST-10</td>
<td>66</td>
<td>66</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>ST-20</td>
<td>81</td>
<td>66</td>
<td>15</td>
<td>81.41</td>
</tr>
<tr>
<td></td>
<td>ST-30</td>
<td>66</td>
<td>66</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>ST-40</td>
<td>73</td>
<td>66</td>
<td>7</td>
<td>90.41</td>
</tr>
<tr>
<td></td>
<td>ST-50</td>
<td>91</td>
<td>66</td>
<td>25</td>
<td>72.52</td>
</tr>
<tr>
<td>Machining process</td>
<td>M/C - I</td>
<td>240</td>
<td>130</td>
<td>110</td>
<td>54.16</td>
</tr>
<tr>
<td></td>
<td>M/C - II</td>
<td>240</td>
<td>130</td>
<td>110</td>
<td>54.16</td>
</tr>
<tr>
<td>Bush pressing process</td>
<td>ST-120</td>
<td>128</td>
<td>66</td>
<td>62</td>
<td>51.56</td>
</tr>
<tr>
<td>Quality Checking</td>
<td>GP-12</td>
<td>102</td>
<td>66</td>
<td>36</td>
<td>64.70</td>
</tr>
</tbody>
</table>

Fig. 3. Time Study result
Fig. 2. Current state of VSM
5S adoption

As 5S is an initial step before the standardisation of work, the area for storing the finished good has been redefined for different materials by considering the principles of the 5S. Spaghetti diagram is a lean manufacturing tool that was used to monitor the material flow movement within the production plant [10]. It helps in identifying the redundancy in material flow and to find out optimal plant layout on the basis of the distance travelled by the worker for material handling and subsequently the material flows were optimized.

Kaizen 1: Implementation of gravity conveyor between Weld Stations:

Further, observation was that the transfer of the assembly from one station to next station is also taking longer time which also adding the non-value added time for the next work station to perform an operation. This time consuming activity was improved by using the gravity conveyor as shown in Fig. 4 instead of just using a stand in which the operator need to push the assembly till the next station.

Kaizen 2: Implementation of combination tool at Machining Centre I & II:

Earlier two different machining process drilling and chamfering were performed at two different time that was increasing the machining time therefore combine cutting tool was suggested as shown in Fig. 5 which can perform both the operations at the same time which reduced the cycle time of the machining centre.

Kaizen 3: Implementation of checking gauge at Checking Station:

A measuring gauge was designed as shown in Fig. 6 for checking the holes relative position that has made the
checking process easier and time saving. Earlier this checking procedure was carried out manually which was cumbersome and consuming lot of time in checking the relative position of six different holes.

(a) Checking Gauge

Fig. 6. Implementation of Checking Gauge

(b) Checking Procedure

Table II: Cycle time after improvement

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Cycle time before improvement in sec.</th>
<th>Cycle time after improvement in sec.</th>
<th>% Improvement in cycle time</th>
<th>JPH before improvement</th>
<th>JPH After improvement</th>
<th>% increase in JPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-20</td>
<td>73</td>
<td>68</td>
<td>6.8</td>
<td>49</td>
<td>53</td>
<td>8.16</td>
</tr>
<tr>
<td>ST-40</td>
<td>70</td>
<td>66</td>
<td>5.7</td>
<td>51</td>
<td>55</td>
<td>7.84</td>
</tr>
<tr>
<td>ST-50</td>
<td>91</td>
<td>66</td>
<td>27.5</td>
<td>40</td>
<td>55</td>
<td>37.5</td>
</tr>
<tr>
<td>M/C Centre</td>
<td>240</td>
<td>140</td>
<td>41.7</td>
<td>15</td>
<td>26</td>
<td>73.3</td>
</tr>
<tr>
<td>Quality Checking</td>
<td>102</td>
<td>60</td>
<td>41.2</td>
<td>35</td>
<td>60</td>
<td>71.4</td>
</tr>
</tbody>
</table>

Fig. 7. Future State of VSM
IV DISCUSSION

The prime objective of this paper was an application of VSM to identify the various wastes associated with the current work layout and discover the areas of improvements before adopting the lean manufacturing. This improvements were adopted and results after and before the implementation were discussed in Table II and the Future State of VSM was also plotted indicating the improvement actions taken as shown in Fig. 7.

V CONCLUSION

Value stream mapping is a useful tool of the lean for understanding the current production flow and it also provides the information about the types of wastes associated with the current condition. Various lean tools like 5S, spaghetti diagram, and line balancing were used to optimize the current state of VSM and the non-value added activities were reduced. Implementation of these lean tools resulted into decrease in the production lead time from 7.6 days to 3.2 days, reduction in cycle time of the bottleneck stations up to 73% and improving the productivity by the reduction in inventory of WIP. Hence, it is concluded that the application of VSM is the prerequisite and an essential step before the implementation of lean manufacturing.

REFERENCES


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