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Implementation of Lean Tool to Improve Productivity in an Automotive Component Assembly Line

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Abstract

In the present competitive scenario of manufacturing, companies are working towards continuous improvement to sustain the global market. This paper manifests an economical way of identifying the opportunities of improvement using a lean tool Value Stream Mapping (VSM). Bottleneck stations which are the main hindrance to the line productivity are identified and balanced using cycle time analysis and VSM. This helps the company to cope up with the changing demand patterns.VSM is an effective lean manufacturing tool which aids in identification and classification of Value-Added (VA), Non-Value Added (NVA) and Essential Non-Value Added (ENVA) activities. Using VSM symbols the current state was sketched and the opportunities for the improvement were identified in a cost effective manner. Future state was depicted with suggestions from various brainstorming sessions. Continuous improvement techniques were used to implement the suggestions stated in the future state. The suggestions were put to action in the future state which resulted in reduction of total manufacturing lead time by 101 seconds and increased production by 12.9%. On implementing the suggested changes a savings of 11.76% from the total expenditure (to operate one shift) was achieved.This paper provides the true picture of application of VSM to identify improvements which are economically feasible and verified by cost benefit analysis.

Keywords:

Manufacturing Lead Time;
Value Stream Mapping;
Automotive Component Manufacturing;
Cost Benefit Analysis;
Productivity Improvement

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1. Introduction

In today's competitive scenario, it is highly important for the companies to put up with the changing demand patterns. So, the companies have to continuously benchmark and identify the opportunities of improvement for their sustenance in the global market. Thereupon the organisations are forced to look for proven concepts for reduction in Manufacturing Lead Time (MLT), WIP, increase in flexibility of production and improve quality in an efficient and economical manner. Hines and Taylor emphasised that [1] by

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integrating different tools, lean production, a concept based on Toyota Production System (TPS) has emerged as a global approach to eliminate waste and manufacture products that meet the customer's expectation in a better way. The ultimate aim of Lean is centred around creating more value with less effort. Lean manufacturing accelerates the process and eliminates the wastes, thus increasing the overall value for which the customer pays. Though benchmarking is a best method to analyse the performance gaps, it provides only little guidelines regarding bridging of those gaps. A new type of benchmarking, Value Stream Mapping (VSM) serves best in overcoming the above mentioned limitation. VSM, as a [2] benchmarking tool, is used to develop a streamlined supplier network around the distributor of electrical and mechanical components. VSM is a lean tool which is a visual depiction of information flow, Process flow and the timeline of the production processes envisioning with better performance in the future state. For any enterprise that wants to be lean, VSM is the most widely used methodology. The effect of VSM application [3] was emphasised by the reduction of cost of quality and increase in productivity by systematic identification and elimination of waste. VSM provides a good review of various continuous improvement tools like 5S, Kaizen, TPM, Kaikakku (Rapid Kaizen), Heijunka Load Balancing etc., VSM can also be integrated with other tools and techniques for more effective decision making, better and efficient results. VSM is capable of [4] tracking wastes and streamlining the value network and also integrates Quality Function Deployment (QFD) to prioritize waste and eliminate them. By integrating Analytical Hierarchical Process (AHP) with VSM [5], decisions are made to achieve Quality, Cost and Delivery in a single piece flow system which can manufacture various variants of the company efficiently. In this paper an attempt has been made to improve the performance measures of a flow production line in an automotive component manufacturing company which could not sustain the fluctuations in their demand. The Current State (**CS**) value stream was mapped and screened for improvements and the stated suggestions were implemented to achieve the future state. VSM resides in any enterprise having a customer and a supplier. Hence, the application of VSM is not limited only to manufacturing industry, but also extends to any sector which has a value chain, like healthcare, pharmaceutical, sports, food, transportation sectors etc.., VSM approach was used in a pharmaceutical company **[6]** which assisted the company in reducing lead times, cycle times and WIP inventory in the manufacturing process. The lean tool VSM [7] was used toimprove the quality of a physician's clinic by reducing the waiting time of patients, consultation of unscheduled appointments and also lowering the stress levels of clinic's staff.

2. Methodology

VSM is a substantial lean manufacturing tool used to record, analyse and improve the information flow and the material flow to produce the product or service for the customer. VSM is also called an 'end to end system' map which not only takes the activity of the product into account but also the management and information systems that support the basic process.VSM is actually a paper and pencil tool in which initially the **CS** is mapped visualizing the present scenario of the firm. After brainstorming, the Future State **(FS)** was sketched with the envisioned improvements. VSM helps in identification and segregation of the processes into

- Value added activities (VA)
  -Activities that add value to the product.
- Non-value Added activities (NVA)
  -Activities that don't contribute to the product's value.
- Essential Non-Value Added activities (ENVA)
  -Activities that are inevitable but don't add value to the product.

Taylor [8] stated"Value Stream Maps are a very effective method for summarizing, presenting and communicating the key features of a process within an organization". VSM has been approached by many top management professionals and researchers like Hines, Abdul Malek and Rajgopal, Serrano and Singh for identification and elimination of waste (Muda) in production industry. Certain Lean management principles [10] must be taken into concern for VSM implementation, which are as follows : Define value from your customer's perspective; Identify the value stream; Eliminate the eight deadly wastes; Make the work flow; Pull the work rather than push it; and Pursue to perfection level.

3. Case Study

A case study was carried out in an automotive component manufacturing firm comprising of 6 sub-assembly lines and a final assembly line. But, the study was mainly focused on solenoid assembly line due to its criticality with 26 processes in the final conveyor line and 3 sub-sub assembly lines as shown in fig.1. The Solenoid assembly line was often encountered with issues like queuing, breakdowns and other miscellaneous problems that were restricting the firm to meet their fluctuating demands. To sort out the above mentioned issues we decided on applying the lean manufacturing tool, VSM. VSM is a [9] lean tool which provides optimum customer value by removing the waste in the value chain.

3.1 Process Observation

The line had a maximum demand of 3200 products per shift (9.5 hours). A product line with such a demand plays a major role in the total productivity of the firm. At the end of the three sub-sub assemblies an inventory of each was maintained for not more than a shift. Though the line comprised as many as 15 Poka-Yoke (mistake proofing) devices to cater to the quality expectation of the customer, few issues that the line faces are

- Separation and loading of small interlaced torsion springs that often consume more time for the operator, thereby increasing the lead time.
- Increased queuing of products in cap crimping, preheating and auto soldering stations.

These problems remained as a hindrance to their planned production volume. The observed processes were mapped in the form of Process flow charts in figure 2 (sub-assemblies) and figure 3 (solenoid conveyor).

3.2 Data Collection

The Total Cycle Time (TCT) of each process being in seconds, was calculated through video analysis. The Cycle Time (CT) analysis was performed for the entire line and the lead time of the whole assembly was calculated. The constraints considered were start-up loss, end loss, unplanned breakdowns, down time, intervals and ergonomic allowances etc.,

The information collected were

- Demand and Daily Production Plan
- Working hours and man power details
- Cumulative Production Monitoring worksheets were screened for failure data, hourly production, setup & adjustment time, changeover time, unplanned breakdowns and maintenance details.
- Order & Dispatch frequency and transportation mode.

The calculated CT of each process are listed and tabulated in table 2.

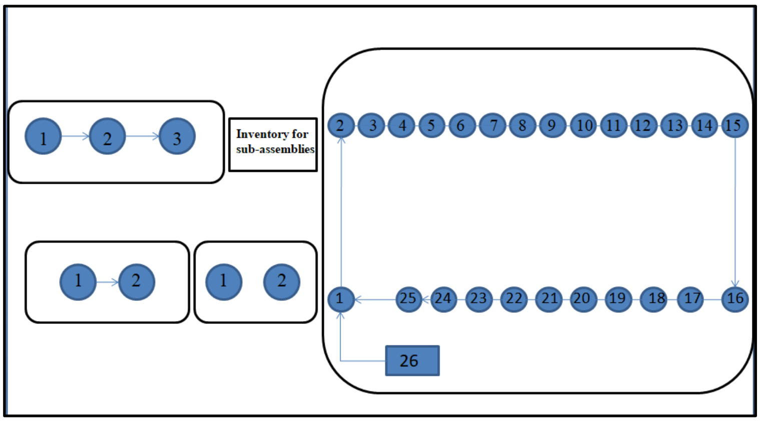

Figure 1. Solenoid Assembly Layout

3.3 Current State VSM

Current state map is a snapshot of the existing processes based on which improvement areas need to be identified. There are three phases in VSM, which showcases the process flow and information, along with the timeline. Timeline gives information about the total process time and lead time for inventory through processes.The current state (CS) VSM was mapped with the standard symbols of the lean tool, which are classified as: Process Symbols; Material Symbols; Information Symbols; General Symbols. “FLOWBREEZE” package was used as an add-in in Microsoft Excel to map the CS using icons to visualize the flow of material and information as the product advances. The information flow was figured out regarding the electronic transfer of information and plan for each day from the production control to each of the assembly lines.

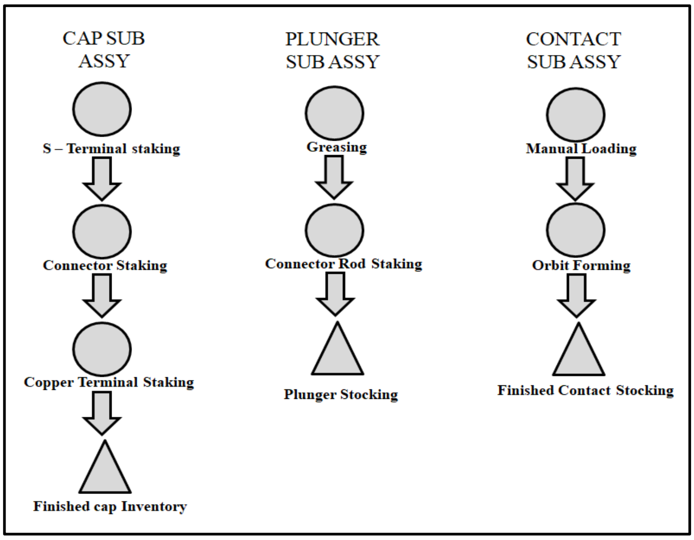

Figure 2. Sub-sub assembly -Process flow

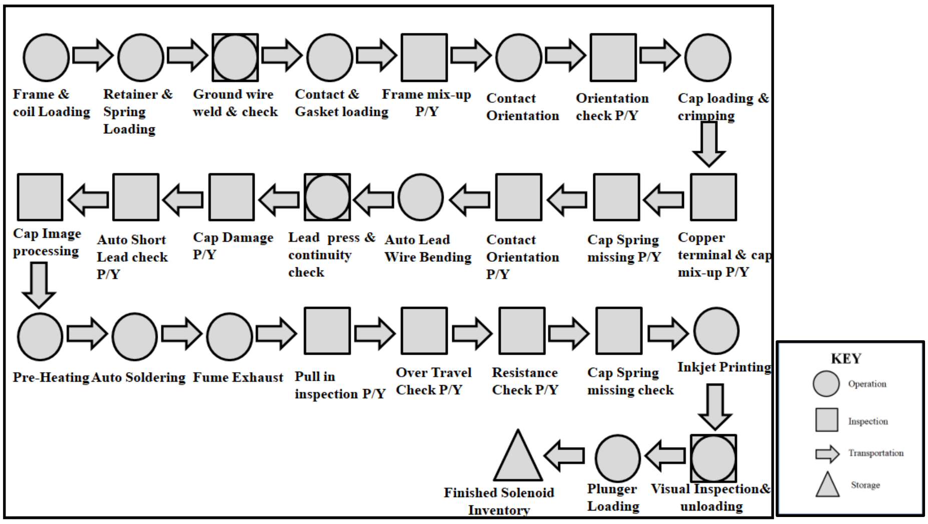

Figure 3. Solenoid Conveyor Line – Process Flow

The Takt-time(T_K) is defined as the rate at which the product must be produced in order to meet the customer demand. Downtime is the time when the line remains un-functional due to planned and unplanned events. Total Downtime (T_D) is calculated (eqn. 1) as the sum of break time (T_B), maintenance time (T_M), Start-up allowances time (T_{SL}), set-up time loss (T_{SU}) and End allowances time (T_{EL}).Effective working time per shift (T_E) (eqn. 2) is the time remaining in the total shift time after excluding Total Downtime. In other words it is the time for which a worker performs his work with the maximum efficiency in one shift. Thus, T_K(eqn. 3) is the ratio of Effective working time per shift to customer demand per shift (D).

$$\mathbf{T_D = T_B + T_M + T_{SL} + T_{SU} + T_{EL}} \quad \text{.....eqn(1)}$$

$$\mathbf{T_E = T_S - T_D} = [570 - (75 + 15 + 10 + 5 + 5)] = \mathbf{460\ minutes} \text{.....eqn(2)}$$

$$\mathbf{T_K} = \frac{\mathbf{T_E}}{\mathbf{D}} = \left(\frac{460}{3200}\right) = \mathbf{0.1438\ minutes = 8.6\ seconds} \quad \text{.....eqn(3)}$$

The process flow was mapped with the data boxes representing the CT, changeover time, and availability along with the manpower number below each process and the inventory between every two stations was calculated. The finished products from the sub-sub assemblies is stocked in the form of the supermarket from which they are pulled (manual pull system) to the solenoid conveyor line in a FIFO (First in First Out) basis. A “push” system was followed between the stations in all the three sub-sub assemblies, whereas in the solenoid conveyor line a “pull” system was followed between each of the stations. The information flow was mapped with the order and dispatch frequency, using the arrows in form of electronic and manual flow. The time line was finally updated by taking all the constraints mentioned in 3.2 into account along with the CT, to estimate the total lead time of the line. The inventory lead time is taken as the sum of start-up loss time, end loss time and other preventive maintenance schedule time. In the case of the solenoid conveyor, the start-up loss and cleansing of the nozzle in inkjet printer (preventive maintenance) each taking about 15 minutes, comprises about 30 minutes (1800 seconds) of the lead time. While in the case of the sub-assemblies the start-up loss of 15 minutes (900 seconds) alone contributes to the lead time. This gives an exact estimate of the total NVA and VA activities.

3.4 Analysis Of Current State Vsm

A maximum demand of 3200 products was taken as the plan. The total shift time was 9.5 hours (570 minutes), in which the effective work time was 7.67 hours (460 minutes) excluding the allowances. A graph was plotted between the process and CT (figure 4), to deduce the bottleneck processes, which was found to be the pre-heating process with 9 seconds of CT. In the same graph the T_K was set as a target line, and it was found that Pre-heating process alone crossed the T_K level, indicating its major hindrance to produce 3200 products. The Lead time (LT) of the sub-sub assemblies and the solenoid conveyor line was calculated separately and the Total Lead time (TLT) of the entire assembly line was computed (eqn. 4) as

$$\mathbf{TLT = \max LT\{A, B, C\} + LT\ of\ solenoid\ conveyor\ line} \qquad \text{.....eqn(4)}$$

Where, A – Cap Assembly, B – Plunger Assembly , C – Contact Assembly

The maximum LT of the above three sub-sub assemblies was that of the cap assembly which was about 985.3 seconds and the LT of the Solenoid Conveyor was estimated to be 2282.4 seconds. From which the TLT of the solenoid assembly line was computed as 3267.7 seconds. In each of the sub-sub-assemblies, the LT of the first product (LT_1) is the sum of the machining and the move time of all the processes. After the first product, each of the forthcoming products is finished at the rate of the longest processing time (T_{LP}) of the line. Hence, the Production (P) in each of the sub-sub assembly is calculated (eqn. 5) as

$$\mathbf{P = \frac{[T_E - LT_1]}{T_{LP}} + 1} \qquad \text{.....eqn(5)}$$

Hence, the current production (table 2) of the entire solenoid assembly line, would be that of production (eqn. 5) of the final conveyor line of 3015 products.

3.5 Building Future State

A keen analysis of the current state VSM is essential to spot out the improvement areas to build the future state of the present line. The plan for the next year of any firm can be arranged accordingly to the future state and the execution of the enhanced changes becomes easier. The future state map answers to the question "what must be achieved and the means to achieve it". The future or 'to be' state serves as a guide until achieving the final goal. The changes done in certain stations of the solenoid line are listed in Table 1. A time period of two weeks was taken for the complete implementation. For the redesigned solenoid line, video CT analysis was carried out again and the revised CT was tabulated (table 3). The actual results were recorded and compared with the expected results in which we found that both were almost similar.

A graph (Figure 4) between processes and CT was plotted for the enhanced solenoid line and was found that CT of all the processes were below the target T_K line, which implies that the demand of 3200 can be met with a T_K of 8.63 seconds.The MLT of the improved solenoid conveyor line was found to be 2181.4 seconds, from which the TLT of the entire line (including the three sub-sub assemblies) was calculated to be 3166.7 seconds. The total (MLT) was decreased by 101 seconds (figure 5) which is about 3.1 % reduction. The production of the redesigned Solenoid Conveyor unit alone was calculated as 3404 units (eqn. 5). This has accounted to an increase of about 12.90 % in the production line, which produces about 389 products more than the former state. By identifying and eliminating the NVAactivites thus optimizing the line, the company is able to meet their demand of 3200, and also at the same time is capable of producing 204 products more (figure 5), to meet slight demand variations.

4. Cost Benefit Analysis

This analysis is done to calculate the percentage of savings spent on the implementation of the suggested changes. The total cost of implementation is calculated in the table (table 4). The total overhead cost per shift is calculated in the table (table 5). The other unconsidered overhead costs do not change with respect to the number of shifts operated. So they have been neglected while calculating the total overhead cost.

Table 1. Suggestions Implemented & End Results

S.No.	LOCATION/OPERATION	PROBLEM IDENTIFIED	CHANGES DONE	END RESULTS
1	CAP LOADING & CRIMPING	There was a delay in ram movement compared to the jig.	Simultaneously start of ram and jig.	The CT of this station is reduced by 1 second.
2	LOADING OF SPRINGS	Interlacement of torsion springs.	The springs are separated & arranged offline in a wire.	CT decrement: Retainer & spring loading- 1.2 seconds and Cap loading & crimping- 2.3 seconds
3	PRE-HEATING	The bottle neck station, having a CT of 9 seconds.	Increased the number of handguns from 2 to 4.	The CT is reduced to 2.5 seconds.
4	FRAME UNLOADING	Handling of finished products was done twice.	Directly placed onto the dispatch tray.	Reducing the CT of this station by 3 seconds.
5	OUTPUT CONVEYOR OF FRAME LOADING	Operator waits due to slow conveyor speed,.	The speed of the conveyor belt is increased.	Reduced move time from 9 to 7 seconds.
6	OUTPUT CONVEYOR OF CONTACT ORIENTATION P/Y	Queuing of products due to high conveyor speed	The speed of the conveyor belt is decreased.	Increased move time 8 to 10 seconds.

Table 2. Production of Current State (CS) and Future State(FS)

SUB-ASSEMBLY	MLT (Sec)		LT_1 (sec)		T_{LP} (sec)		P (per shift)	
	CS	FS	CS	FS	CS	FS	CS	FS
Cap	985.3	985.3	85.3	85.3	7.7	7.7	3575	3575
Plunger	918.8	918.8	18.8	18.8	8.1	8.1	3407	3407
Contact	916.2	916.2	16.2	16.2	7.4	7.4	3729	3729
Solenoid Conveyor	2282.4	2181.4	482	381	9	8	3015	3404

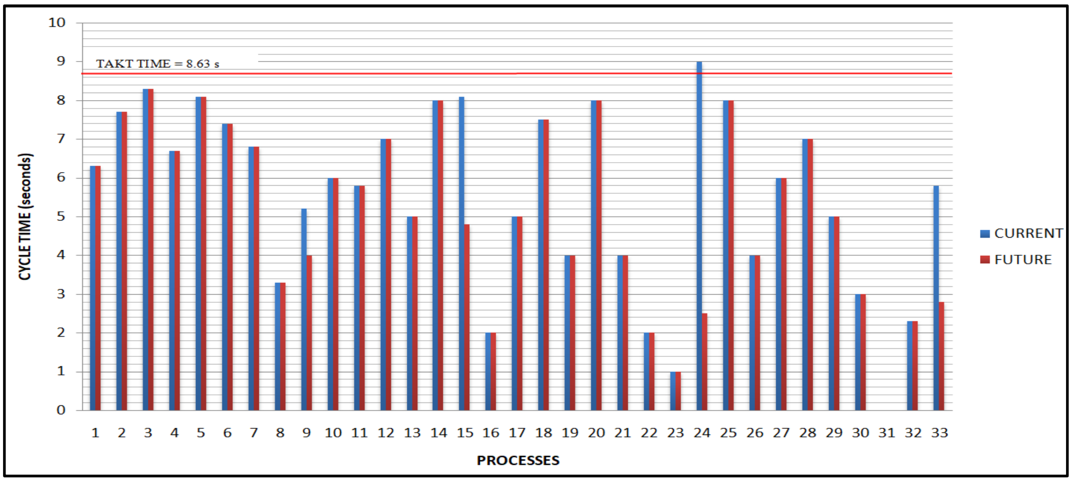

Figure 4. Processes Vs Cycle Time (Current & Future State)

Table 3. Cycle Time – Current State and Future State

S.NO	ASSEMBLY LINES	ACTIVITY		CT		TCT		MAN
				CS	FS	CS	FS	
(i)	Cap Assembly	1	S-terminal staking	6.3	6.3	14	14	3
		2	Connector staking	7.7	7.7			
		3	Copper terminal Staking	7.3	7.3			
(ii)	Plunger Assembly	4	Greasing	6.7	6.7	15	15	2
		5	Connector rod staking	8.1	8.1			
(iii)	Contact Assembly	6	Manual Loading	7.4	7.4	14	14	2
		7	Orbit forming	6.8	6.8			
(iv)	Solenoid Conveyor line	8	Frame & coil loading	3.3	3.3	132	118	6
		9	Retainer & spring Loading	5.2	4			
		10	Ground wire welding & P/Y	6	6			
		11	Contact & gasket loading	5.8	5.8			
		12	Frame mix up P/Y	7	7			
		13	Contact orientation	5	5			
		14	Orientation checking P/Y	8	8			
		15	Cap loading and crimping	8.1	4.8			
		16	opper terminal & cap mix up P/Y	2	2			
		17	Cap spring missing P/Y	5	5			
		18	Contact Orientation P/Y	7.5	7.5			
		19	Auto lead bending	4	4			
		20	Lead press & continuity check	8	8			
		21	Cap damage	4	4			
		22	Auto short lead check P/Y	2	2			
		23	Cap Image processing	1	1			
		24	**Preheating**	**9**	2.5			
		25	Auto soldering	8	8			
		26	Fume exhaust	4	4			
		27	Pull in inspection P/Y	6	6			
		28	Over travel checking	7	7			
		29	Resistance check P/Y	5	5			
		30	Cap spring missing check	3	3			
		31	Inkjet Printing	0	0			
		32	Visual inspection & unloading	2.3	2.3			
		33	Plunger loading	5.8	2.8			

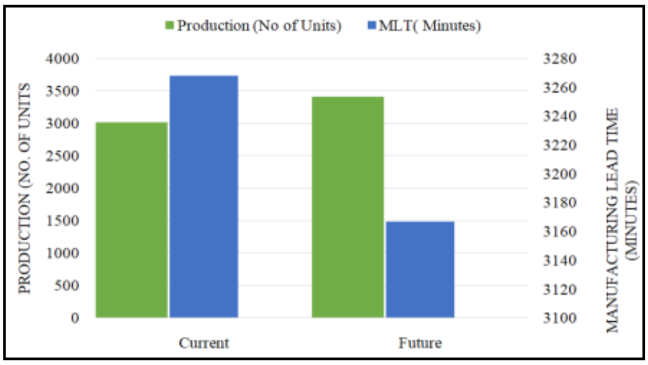

Figure 5. VSM States Vs Production and MLT

Table 4. Cost of Implementation for Each Station

S.No.	**STATION**	**CHANGES DONE IN**	**COST OF IMPLEMENTATION**
1	Cap Loading & Crimping	PLC Program	No cost incurred
2	Spring Loading	Arrangement of springs	Wire for 200 meter. Cost of 200 m = Rs. 1412
3	Pre-Heating	Hot air handgun installation	2 new handguns added Total cost = Rs. 4000
4	Frame Unloading	Placements of finished products	No cost incurred
5	Conveyor Between Frame Loading & Spring And Retainer Loading	Conveyor Belt Speed	No cost incurred
6	Conveyor Between Contact Orientation P/Y & Auto Short Lead Check	Conveyor Belt Speed	No cost incurred
TOTAL COST OF IMPLEMENTATION			Rs. 5412

Table 5. Total overhead cost per shift

S.No.	TYPE OF OVERHEAD		COST INCURRED
1	Wages per Operator per shift	Skilled = Rs. 750	[(750*7)+(500*6)]= Rs. 8250
		Unskilled = Rs. 500	
2	Electricity consumption	Cost per unit = Rs. 6.35	(6.35*300) = Rs. 1905
3	Food & others	Cost per employee = Rs. 59	(59*13) = Rs. 767
TOTAL COST OF OVERHEADS PER SHIFT			Rs. 10967

Over the implementation of the subjected changes in the FS the plant is enabled to produce 389 products more than the production that was in the CS. This leads to reduction in the total number of shifts required to complete the entire order of the customer which in turn results in saving the total overhead cost incurred in those saved shifts and rescheduling those shifts to the forthcoming orders. For instance, consider an order of 1,00,000 products. The capacity of the current state being only 3015 products, the number of shifts taken to complete the order is $33\frac{1}{6}$shifts (≈34) whereas the capacity of future state being 3404 products, the number of shifts taken to complete the order is just $29\frac{2}{5}$ shifts (≈30). The total overhead cost being Rs.10967, the percentage of savings can be calculated as follows:

$$\text{Percentage of Savings} = \frac{[(34*10967)-(30*10967)]}{(34*10967)} * 100 = 11.76\%$$

Thus the implemented changes ensure a savings of 11.76% and the saved shifts can be allocated for further production.

5. Conclusion

This paper demonstrates a flow production line in a starter motor which is unable to meet the stated demand due to presence of waste leading to inefficient utilization of the sub-assembly line. By rapid brainstorming and process flow mapping, VSM was mapped for the current and future state with few improvements. The Total MLTwas reduced by 101 seconds (3.9%) resulting in a production increase of 389 products (12.9%) per shift enabling the firm to meet its demand of 3200 while promising 11.76% cut from the total expenditure. Thus a substantial increase in revenue to the firm is obtained in a cost effective manner. The purview of this study was limited to VSM implementation in only one of the lines, if it is done for all other sub-assembly lines in the firm, it would further lead to significant increase in production. Thus, proper streamlining and continual optimization of the value stream ensure success to any enterprise.

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