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ORIGINAL RESEARCH PAPER

The Impact of Productivity Improvement Approach Using Lean Tools in an Automotive Industry

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Abstract
In today's competitive environment, as manufacturing industries face additional pressure to meet the dynamic nature of customer demand, lean manufacturing is an essential tool to reduce this burden to a great extent. Various lean methodologies exist like value stream mapping, 5S, Kaizen, line balancing, just-in-time, poka-yoke, Kanban, total preventive maintenance, and single-minute exchange of die, which are currently being implemented in industries for the improvement of productivity and reduction of overall cycle time. The study discusses the importance of combining value stream mapping and line balancing techniques using existing literature and is validated by a case study on an automotive component manufacturing industry's assembly line. In the past, lean tools have been criticized for being static tools due to a lack of measurable output due to the implementation of the techniques. In this study, the real-world performance of value stream mapping allows for clear understanding and accurate prediction in terms of cost and time savings achieved using lean tools. Value stream mapping is a highly beneficial lean tool for industries with constrained resources to assess the considerable gain lean tools would provide and how the long-term investment would be beneficial to offset non-value adding activities. The empirical validation shows a reduction of the overall time cycle by 20.28% and a gain in the number of units produced by 46.16%. The results also demonstrate that an increase in productivity by eliminating waste (through value stream mapping) and modifications in the layout and assigning an appropriate number of workers (through line balancing) is possible after careful assessment.

Keywords Value stream mapping (VSM) · Kaizen · SMED · Just-in-time (JIT) · Line balancing · Cycle time · Layout planning · TPM · Kanban

Introduction

To gain a competitive edge and enhance productivity, automotive manufacturers have transformed their philosophy in favor of the lean production paradigm. Lean manufacturing focuses on eliminating waste (overproduction, excess inventory, unnecessary motion, over-processing, waiting time, defects, and extra transportation) in current practices by identifying non-value-adding activities in a production cycle (Rajesh 2015). Value stream mapping (VSM) is one of the pioneer lean manufacturing tools that intends to provide a clear picture of information and material flow at every stream from the supplier to the factory and finally to the customer. Visual and detailed data can be extracted by zooming out a stratum of VSM at the process level. The data can be material flow within a cell or production line or at the factory level or door to door in which material flow is within the factory's four walls. One can analyze the macroscopic view to use an extended level of VSM up to various logistical activities (Sheth et al. 2014). Line balancing (LB) is also a lean tool that aims to group the different facilities and equipment into different work stations to minimize idle time and utilization while developing a product-based layout (Swapnil et al. 2014). Efforts made to cut down the cost and improve the efficiency of the process finally increase the output without compromising quality, which further leads to better customer satisfaction (Saraswat et al. 2015).

The objective of the study is to use a real-time case-based approach to determine how lean methodologies like VSM, LB, and Kanban can be utilized to improve the current and existing processes and establish a better inventory and process control.

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The data collection is done in an automotive component manufacturing industry based in Pithampur, India. The results obtained from the implementation of the lean tools show the advantages industries can leverage and the multiple degrees of improvement based on the broad outcomes and objectives of the industry. Therefore, this study will allow better utilization of resources (man, machine, material, etc.) in the future.

The following research questions are addressed in the study:

- *RQ1* How to successfully implement lean tools in a resource-intensive industry involving high movement of parts
- *RQ2* How to minimize the number of stations currently in operation to reduce overcrowding to allow the improved focus of VSM and Kaizen effort
- *RQ3* What are the gains in terms of overall cycle time reduction, units produced, and other resources to allow profit maximization

VSM can thus be defined *as an improvement strategy to link the lean initiatives and the needs of top management with the needs of the operations group through systematic analysis and data capture* (Tapping et al. 2002).

The study is divided into (6) sections starting from the Introduction Sect. (1) to allow readers to understand the multiple lean tools present for industry implementation. The second Sect. (2) gives a brief history of lean theories, tools, and a brief literature review. The various lean strategies (LS) adopted by the previous studies are summarized in Table 2 to identify the most prominent tools implemented by the industries.

The methodology is covered in the third Sect. (3), including the analysis and comparison of the lean metrics of the current state VSM and the future state VSM. The results are discussed in the fourth Sect. (4), and a graphical representation of the improvement in terms of takt time and units produced before and after implementation of lean tools is given in Fig. 12. The conclusion of the overall study is provided in the fifth Sect. (5).

The limitations and future scope of research are discussed in the sixth section.

Sustainability in Manufacturing The study incorporates sustainability by waste reduction, which is summarized in Table 1. Lean and sustainability go hand-in-hand as in manufacturing; it is imperative to allow profit maximization by waste reduction since overhead costs are fixed. Thus, competitive advantage is possible only by focusing on waste reduction using lean tools.

Literature Review

Historical Background of Lean Theory

Eli Whitney was a reputed face to invent cotton gin, a small accomplishment compared to his perfection of interchangeable parts in 1799. For 100 years, manufacturers primarily focused on their unique technologies. At the end of the nineteenth century, people were interested in logistical activities. They started closely observing the flow of material and what was happening between the processes and their arrangement and sequence. Frederick and Taylor start looking at workers and their way of doing work, and the result will come in the form of "time study" and "standardization of work."

Further, Frank Gilbreth adds "motion study" on this. In 1910, Henery Ford focused more on elements of the manufacturing system like (man, material, machine, tools products), etc. They first arranged all these elements in a sequential manner termed the "Ford production system" (FPS). In 1937, Toyoda (later Toyota) was founded in Koromo (Japan), and Kiichiro and Ejji, together with Taiichi Ohno, researched existing FPS and produced perfection in "Toyota production system" concepts and tools. Just-in-time (JIT) can be said to be a core element of TPS. After the oil crisis in North America in 1973, Americans also studied TPS and implemented it in their industries. The first scientific

Table 1 Achieving sustainability by three levels of waste reduction. Source: adapted from Value Stream Management (Tapping et al. 2002)

Level one Gross waste	Level two Process and method waste	Level three Micro waste within process
• Work-in-progress - Poor plant layout - Rejects of damage product - Returns due to defects - Rework due to out-of-tolerance limits - Container and batch size - Poor lighting - Dirty equipment - Material not delivered to the desired destination	• Line balancing - Poor workplace design - Poor maintenance - No fixed storage spaces - Equipment mishap - Unsafe method of operation	• Ergonomic posture - Double handling - Excess walking - Search for stock - Paperwork - Speed and feed - No standard operating procedure

Table 2 A brief summary of the literature review

S. No	Author(s) and year	Industry	LS method adopted	Description
1	Womack et al. 1990	Aircraft and airworthiness operation	Value stream mapping, waste reduction, optimize resource utilization	The primary objective of a lean production system (LPS) is to increase quality and cost savings by removing waste from any production system
2	Kruse et al. 2002; Venkataraman et al. 2014	Lean production	Waste elimination, minimize inventory, maximize flow	The LPS is the arranged method to define and remove all wastes by regular improvement to satisfy customer loyalty
3	Xinyu and Lijian 2009	NA (combined framework of material flow analysis and value stream mapping)	Material flow analysis, value stream mapping	To provide the integrated framework to simultaneously apply VSM and material flow analysis to identify cost and pollution problems
4	Rahani et al. 2012	Automotive manufacturing plant	Lean production principles, value stream mapping	To conduct a case study by using VSM in which she divides the total time in man time and machine time and reduces both 16.9% and 14.17%, respectively
5	Yadav et al. 2012	Railway spring manufacturing company	Value stream mapping	LPS consists of many powerful tools that are deployed to identify and eliminate waste (Muda), like VSM, single-minute exchange of die (SMED), standardization of work, 5S methodology, etc
6	Sreelekshmy et al. 2013	Welding industry (MSME)	Process flow analysis, value stream mapping	Waste can be categorized in multiple ways, but in production systems, unnecessary inventory, delay or waiting, transportation and extra motion, processing, underutilization of resources, and defective parts are considered a waste of resources
7	Murali and Nagaraja 2014	Pump unit manufacturing industry	Lean production principles, value stream mapping	The VSM method can be understood as a visualization tool oriented to Toyota's version of lean manufacturing, which helps understand and streamline work processes and demonstrate wastages in the current process
8	Sheth et al. 2014	Automotive industry	Value stream mapping	To deploy the VSM technique in Lear Corporation to improve lead time by 66.7% and reduce non-value-added time by 25.6%
9	Swapnil et al. 2014	Automotive assembly line	Line balancing, takt time	To identify bottleneck stations and successfully conduct time study, finally eliminating extra activities and improving line efficiency
10	Amir and Thulasi 2015	Electronic components manufacturing small medium enterprise (SME)	Waste elimination, value stream mapping, Kaizen	To implement SMED to minimize lead time and draw future VSMs successfully
11	Verma and Sharma 2016	Green manufacturing	Value stream mapping, lean manufacturing	To explain the new energy value stream methodology (EVSM) philosophy for looking one step ahead from lean with green manufacturing
12	Pambhar 2017	Molded case circuit breaker (MCCB) manufacturing industry	Value stream mapping, cycle time reduction, material flow analysis, layout improvement	To implement VSM as a lean tool in a molded case circuit breaker (MCCB) manufacturer company reduced throughput time from 1230 to 898 s
13	Dinesh et al. 2019; Saravanan et al. 2018	Automotive assembly line	Inventory reduction, value stream mapping, line balancing	To provide a case study of applying the combined concept of VSM and LB and enhance the assembly line's productivity while simultaneously optimizing the workforce
14	Leong et al. 2019	Manufacturing industry	Lean tools, Kanban, value stream mapping	To identify the benefits and similarities in lean and green manufacturing, the synergy, application tools, and the associated misconceptions

Table 2 (continued)

S. No	Author(s) and year	Industry	LS method adopted	Description
15	Rosin et al. 2019	Industry 4.0	Just-in-time, Jidoka, waste elimination	To identify the impact of Industry 4.0 on various lean tools based on the capabilities. The most relevant tools identified are just-in-time, Jidoka, and waste reduction. The need for deployment of lean management while refining lean principles in coherence with Industry 4.0 is explained
16	Yang et al. 2020	Semiconductor crystal-ingot	Taguchi optimization, pulling strategy	Taguchi-based simulation optimization is performed for a robust system. The performance of the system in throughput and service level increases from 6.42 to 12.02%
17	Mahmood 2020	Yarn manufacturing process	Value stream mapping, simulation	Lean tools are used to improve synergy and reduce labor-related workflow. A detailed current value stream mapping (VSM) is used to highlight and map the bottlenecks of processes during the case study validated in Pakistan at a spinning mill
18	Melin and Barth 2020	Swedish dairy farm	Value stream mapping, lead time	The use of VSM shows a positive correlation between green and lean key performance indicators
19	Balaji et al. 2020	Industrial Internet of Things (IoT)	Process flow analysis, value stream mapping	The bottleneck processes are monitored and eliminated or reduced to the minimum using expert guidance, and the use of VSM allows the dynamic sensor-based efficient monitoring system
20	Kumar et al. 2020	Automobile industry	Lean manufacturing	To identify the critical success factors (CSFs) to deploy sustainable lean manufacturing using expert guidance and interpretive structural modelling (ISM) methodology to achieve economic, social, and environmental excellence
21	Nadimuthu and Victor 2021	Ayurvedic medicine manufacturing unit	Process flow mapping, waste elimination	Energy-saving measures are studied by process flow analysis focusing on power quality issues. Various lean tools like process and energy flow mapping are employed, and high energy savings are achieved
22	Shahedi et al. 2021	Automobile industry	Sustainable closed-loop supply chain network, stochastic programming	A sustainable closed-loop supply chain network model is used to minimize the effect of pollutants and maximize profits and employment using facilities to cope with the uncertainty in the demand and the number of returned non-functioning vehicles
23	Goswami and Behera 2021	Material handling equipment (MHE) selection	Just-in-time, process flow mapping	Three real-time material handling equipment (MHE) are selected, conveyor selection, selection of robots, and automated guided vehicles (AGV) using two MCDM methods, complex proportional assessment (COPRAS) and additive ratio assessment (ARAS)

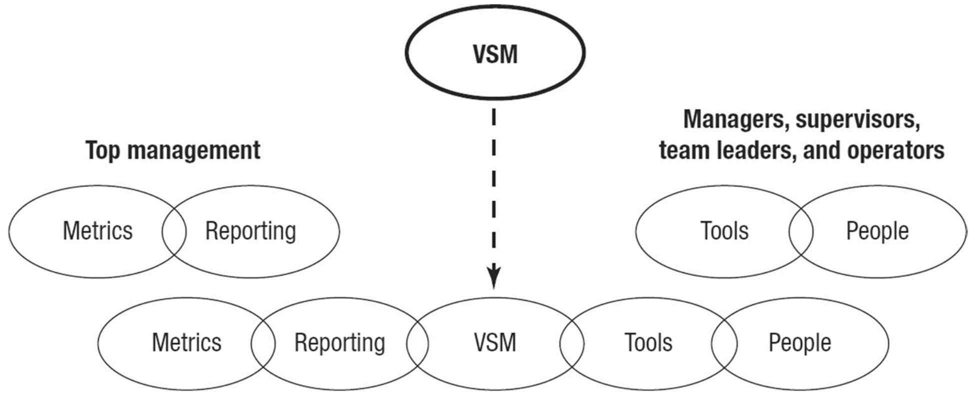


Fig. 1 VSM positioning in the industry

paper was published in 1977 (Sugimori et al. 1977). Articles focused primarily on such issues as Kanban and JIT (Monden 1981). Books such as Monden's *Toyota production system* (Monden 1983) and Ohno's *Toyota production system: Beyond the large production scale* (Ohno 1988) were released. These books very well describe the theory of lean in TPS. In 1990, Womack, Jones, and Roos published the famous book *The machine that changed the world*, which describes lean principles in detail. In 1996 again, Womack and Jones extended the philosophy of lean and its guiding principles at an enterprise level in their book *Lean thinking* (Womack et al. 1996). Consultants and researchers continue to contribute to overarching lean principles; some are visionary (Hopp and Spearman 2004), and some provide realistic relations (Shah and Ward 2003). A brief literature review is given in Table 2, citing the most relevant work related to the lean strategies adopted with a brief description of the study (Fig. 1).

Sustainability by Waste Reduction

The wastes in the manufacturing industry are mainly of seven types, as mentioned below. The levels of waste that typically exist in the automotive components manufacturing industry are classified based on the levels of identification, and Table 1 summarizes the wastes based on different levels:

- *Overproduction:* production of components or goods that are stored in the inventory and not sold immediately leads to excess use of raw materials, workforce, and resources.
- *Transportation:* in a poor plant layout, unnecessary movement of components takes place, leading to an increase in the overall cycle time and use of excess workforce.
- *Waiting:* due to non-optimized line balancing, operators or workers spend time on the assembly line waiting for material or component processing from the previous operator, which needs to be eliminated.
- *Processing:* during processing, it is necessary to identify the precise amount of processing for the desired output in terms of component manufacturing. Over-processing leads to wastage of resources, and under-processing leads to out-of-tolerance components.
- *Inventory:* the excess production leads to a higher stock of components, leading to higher carrying costs and stocking costs.
- *Motion:* due to a poor ergonomic posture, unnecessary body movement takes place, which causes joint pain and inefficiency in manufacturing.
- *Defects and damaged goods:* production of defective and damaged components causes one of the highest wastage in any organization. Thus, it should be identified as early as possible and eliminated.

Methodology and Case Study

The process of lean application starts with problem identification which is done to recognize the lean tool to be used by the organization. The subsequent processes are clearly mentioned in Fig. 2 using a flow chart.

Overview and Process Background

The research validation was done in an automotive component manufacturer company located in Pithampur, an industrial area near Indore, Madhya Pradesh, India. The assembly line chosen for the case study manufactures turbochargers for off-road duty machinery like generators and construction machines, submarine ships, and road vehicles like heavy-duty trucks. Due to the variety of applications of this product segment, the demand is very responsive. It's a challenging task for the management to meet this fluctuating demand as per customer requirements. A cross-functional team was constituted to observe the assembly line closely. It was decided to implement a combination of both VSM and line balancing as a lean tool to improve productivity. The data

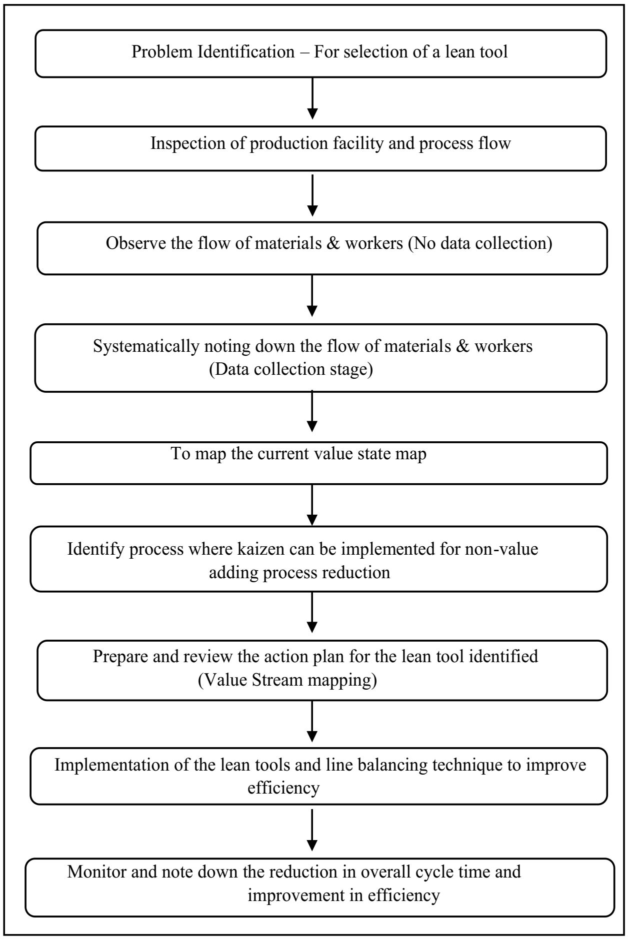


Fig. 2 Flow chart of VSM

collection is done by direct observation followed by operators' responses. A stopwatch is used to record the cycle time (CT) and change over time (CO), and time is taken due to motion by the operators and products. A process flow chart is shown in Fig. 3, and its notations shown in Fig. 4 represent and illustrate the sequence of various activities performed on the assembly line.

The activities performed and the associated description and the machine used to perform the operation are summarized in Table 3.

The position of various stations and facility layouts of current processes is shown in Fig. 5 to identify the bottlenecks in the assembly of the components.

Operations include two shifts running daily with 8 h per shift. The current demand is 130 units per day. For this, five operators are working in different workstations. Takt time is the time that the customer provides, and it is the time required to meet the customer's demand.

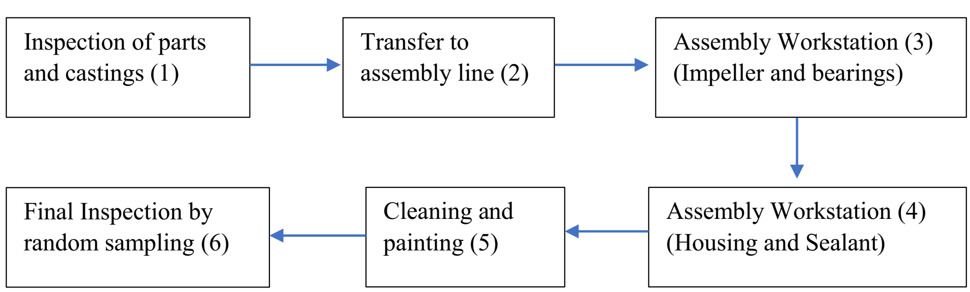
Takt time deals with how frequently the product or part is obligatorily needed, usually by the buyer (Kumar and Kumar 2014). Technically, takt time is the ratio of available time to customer demand. In this case, after removing the allowances, the total remaining net time is 6.5 h/shift, and then the takt time is

$$\begin{aligned}\text{Takt Time} &= \frac{\text{Available time}}{\text{Customer demand}}\\ &= \frac{6{\cdot}5\times2\times3600}{130}\\ &= 360\text{s or } 6\text{m/unit}\end{aligned}$$

Cycle time is the amount of time for which a job to be assembled remains in a workstation. The time required to accomplish a specific activity or task at each well-defined station helps understand the time gap between successive products coming out from an assembly line (Patel and Shah 2014; Nguyen and Do 2016). Even the processing time of each work station is the cycle time of the respective work station. The station whose cycle time is greater or nearer to the takt time is termed a bottleneck station. A bottleneck is identified as some utilities and resources which heavily affect and limit the performance of any production system (Wang et al. 2005). The bottleneck is the central area of interest for improvement by management. Any increment of cycle time on the bottleneck station will directly affect productivity. In this assembly line, two stations, 1.3 and 3, are the most time-consuming and can be considered bottleneck stations that require optimization. Table 4 shows the cycle time and the takt time for each station. A graphical presentation of the difference in takt time and cycle time is shown in Fig. 6.

Note that in operation 10, 4 parts are coming out simultaneously from the washing machine to divide the total time into four parts. It means there is no constraint concerning 300 s. It takes 75 s for each set of jobs. Operation 5 can be

Fig. 3 Turbocharger assembly process



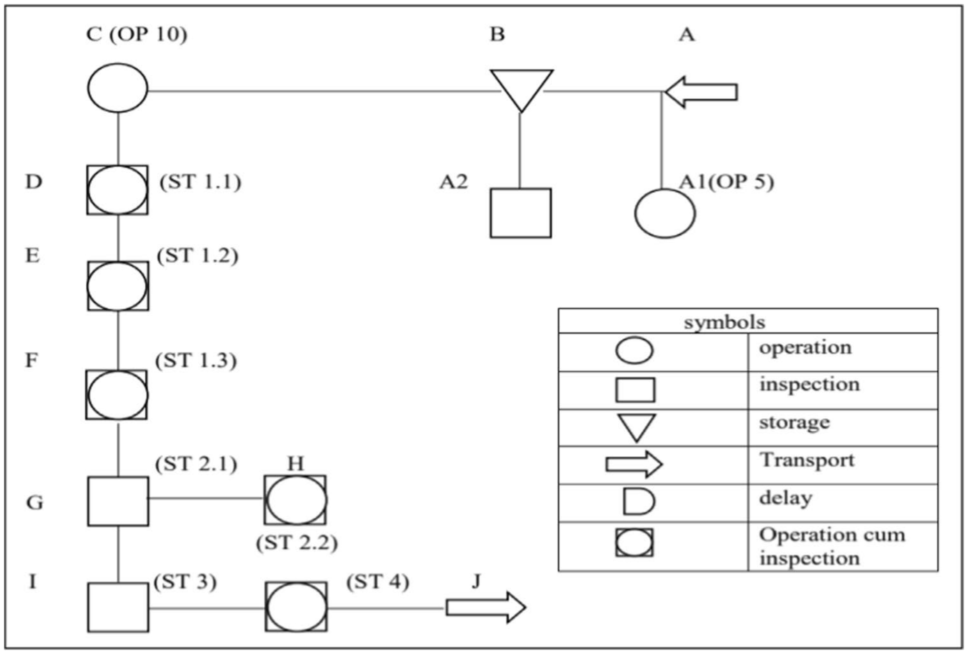


Fig. 4 Flow process chart of existing process

neglected because of its limited use for some specific models for a concise time. Operations 2 and 2.2 are combined and handled by a common operator. After the identification of the bottlenecks, the cycle time and the takt time of each station are given in Fig. 7.

Implementation of Sustainability

VSM is considered the best lean manufacturing tool. The current state is depicted along with the future state that illustrates the hidden wastes within processes or services (Dinesh et al. 2019). The difference between current and future states is realized by recognizing and implementing Kaizen to eliminate waste from systems and processes. There are various symbols used to show the flow of material and information. At the bottom of VSM, a time ladder provides value-added and non-value-added time separately for each operation. The flow and other operational elements are represented through particular symbols and summarized in Fig. 8.

Line Balancing As evident from the previous feedback, the process flow is not balanced and smooth. The current state VSM in Fig. 10 shows the visual flow of the process. The

Table 3 Presentation of the existing processes

Activity	Description	Machine
A	Transport all the parts (bearing housing, compressor housing, turbine housing, diffusor, impeller, etc. from stores to bin	Transport
A1	Thread plug assembly (offline process used very rare case)	Small station
A2	Inspection of the thread plug assembly	——
B	Parts placed in bins and trolley	Trollies
C	Washing of impeller, shaft and wheel, thrust collar, oil slinger	Washing machine
D	Assembly of the roll pin, retaining ring, and journal bearing	ST 1.1
E	Assembly of shaft and wheel and oil slinger with piston ring and diffusor plate with oil slinger	ST 1.2
F	Assembly of the heat shield, thrust collar, thrust bearing, shim, oil baffle, washer, oil nut assembly of the core with the above parts	ST 1.3
G	Pressure test	ST 2.1
H	Core balancing by low-speed core balancer (LSCB)	ST 2.2
I	Assembly of turbine and compressor housing, V band, inspection of band orientation, turbine and compressor housing orientation, spin test	ST 3
J	Antirust oiling and packaging, fixing of data plate as well as labeling	ST 4
K	Transferred the finished product to the dispatch area	Transport

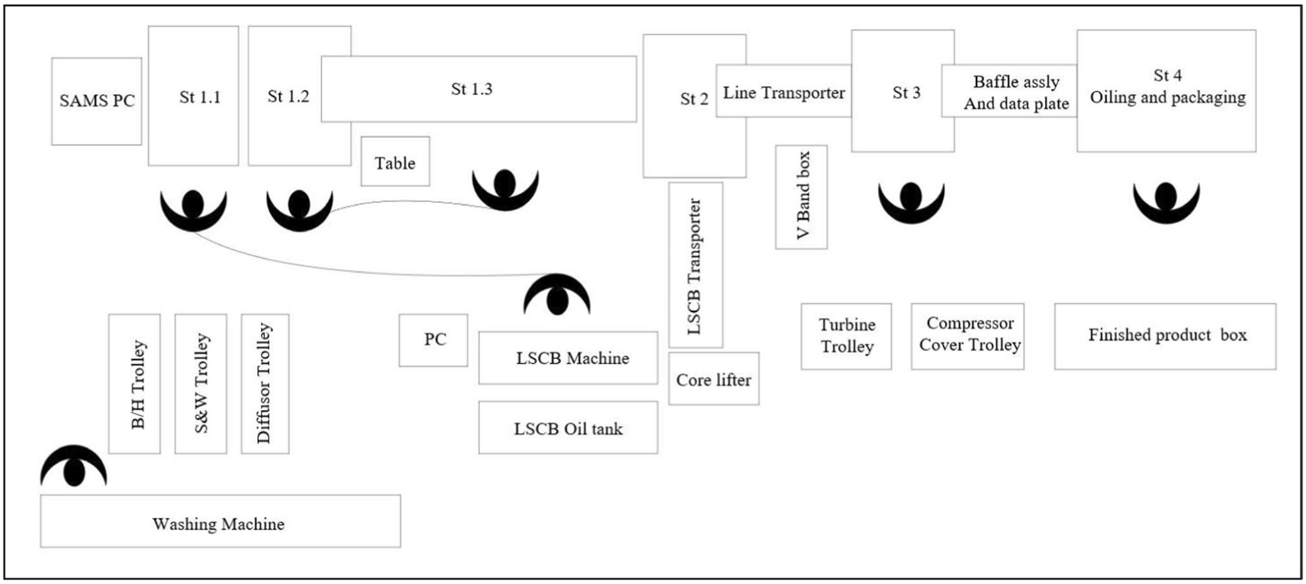


Fig. 5 Current layout of existing processes of the assembly line in the plant

Table 4 Presentation of cycle time and takt time

Op./station no	Takt time (in s)	Cycle time (in s)	Difference between takt and cycle time
10	360	300	60
1.1	360	80	280
1.2	360	25	335
1.3	360	330	30
2 & 2.2	360	90	270
3	360	350	10
4	360	150	210

presence of workstations and manual movement of components lead to a loss of productive operating time. Hence, the LB concept is introduced to ensure equal distribution of overall cycle time, taking it closer to the takt time. The overall gain in the takt time is 2.1 min.

Ergonomic Posture Continuous standing and operating, the stations lead to hand and shoulder pain. Balasubramanian et al. (2011) study shows that working without adequate breaks for nearly 8 h leads to the deterioration in the physical health of the operator. Hence, measures are to be taken to improve the situation. A multiple spindle torque tool, as shown in Fig. 14, is proposed to allow faster work time and reduce the number of movements of the operator. The multiple spindle torque tool provides more reliability during functioning to reduce components' failure.

By observation and calculation, it is estimated that the operator bends around 200 times during the 8-h shift to pick up components and place them in the sorting case. The movement of the components is continuous during the shift. Poor posture makes it difficult for the operator to work with optimum efficiency by the end of the shift. The posture also leads to fatigue and strain, resulting in musculoskeletal disorders (MSD).

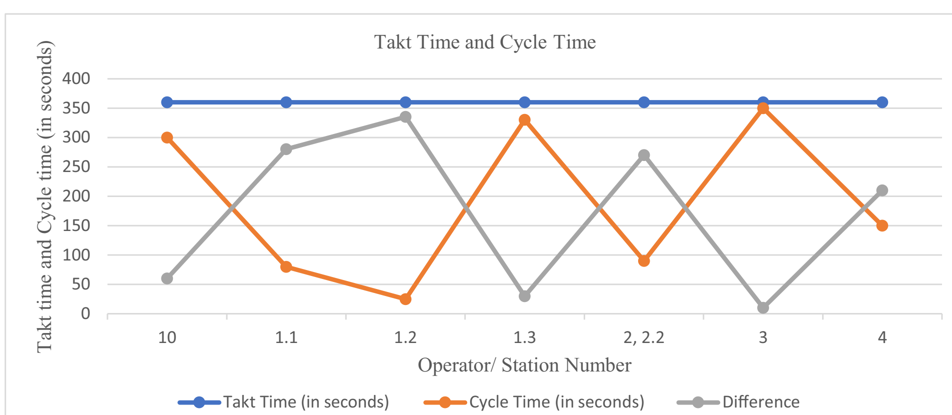


Fig. 6 Cycle time and takt time difference

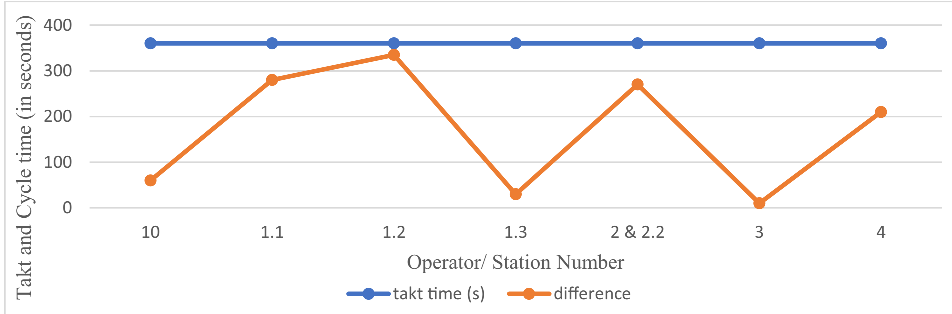


Fig. 7 Identification of bottleneck station

The use of trolleys with bins on the top to stop bending during retrieval and sorting of components is suggested for immediate action, and automation using conveyors is recommended for the future. The improvement in cycle time is indicated in the sixth section in much greater detail.

VSM methodology is described in detail in Fig. 9 to showcase the implementation of five steps in which the first four lead up to the actual improvement of the processes.

VSM Current State Map It records all the facts as they are present in real-time. The record creation

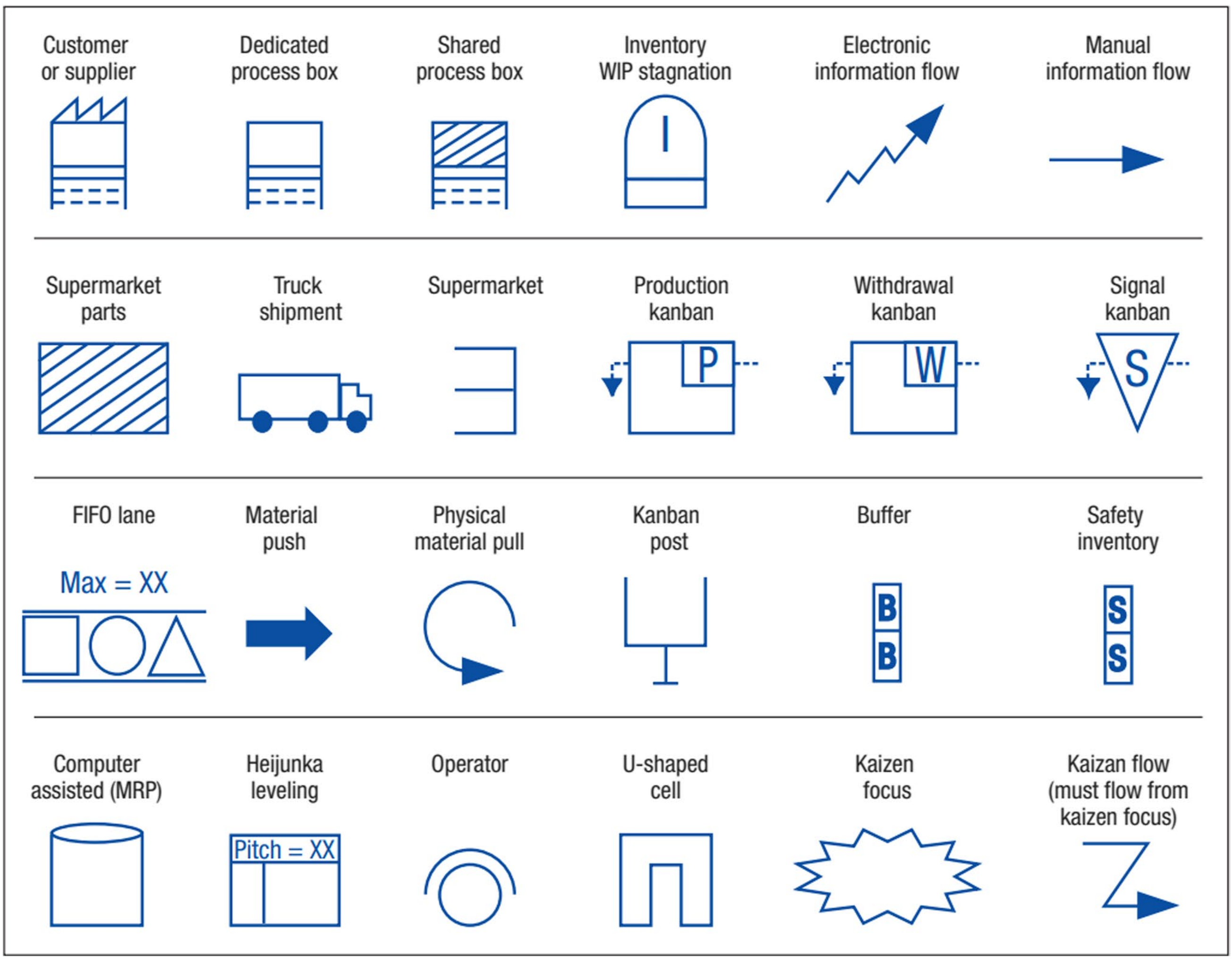


Fig. 8 Presentation of VSM symbols. Source: Value Stream Management (Tapping et al. 2002. Page 79)

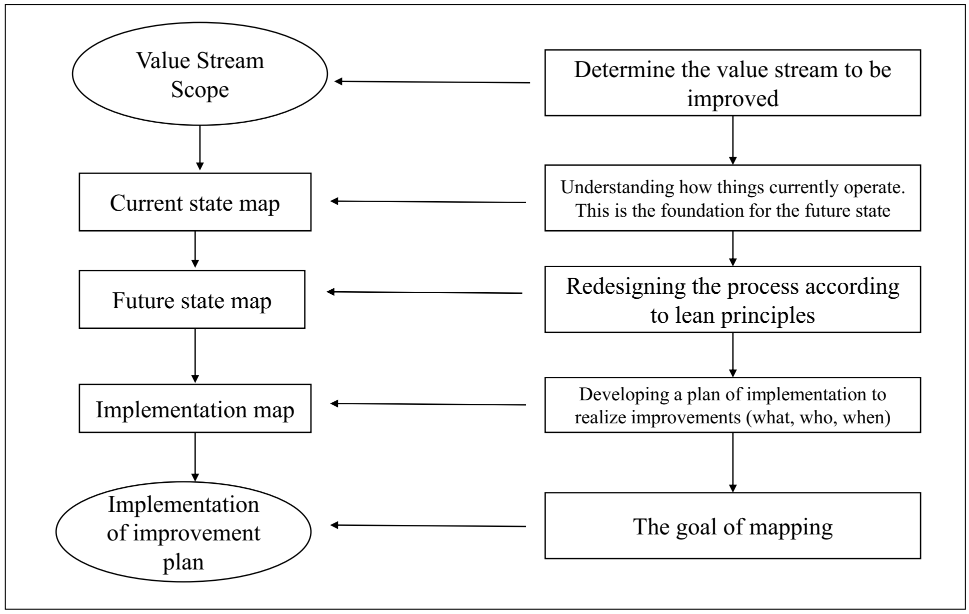


Fig. 9 Steps of the VSM process. Source: authors

of all the observations and data collection is done by visual inspection and by noting down process data (cycle time, number of the operators, changeover time). The activities are further divided into value-added and non-value-added activities. Lastly, data analysis is done, and VSM and LB are deployed to increase the overall output by implementing Kaizens (Fig. 10).

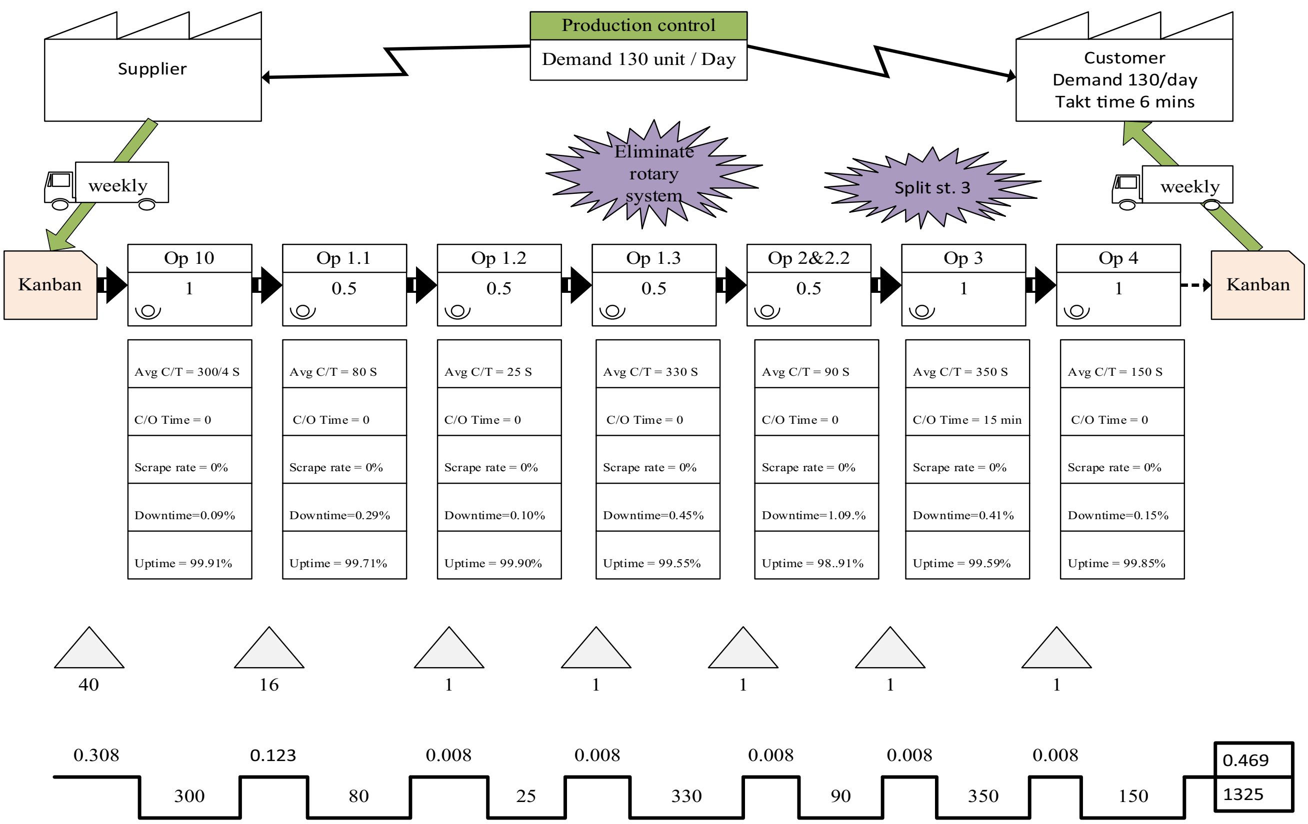


Fig. 10 Current state VSM

Table 5 Kaizen opportunities for creating future VSM

Operator/station No	Observed opportunities	Action plan	Benefits
1.2 & 1.3	Equipped St. 1.2 and 1.3 together	Two tables should be deployed in front of St. 1.3 to split St. 1.2	Reducing the operator motion from one to another station
1.3	Elimination of rotary	Automated rotary replaced with the manual operated fixture	Reducing the cycle time
1.3	Wastage of time for tightening the bolt using a single-spindle system	The multi-spindle system can be used for tightening the bolt	Reducing processing time
1.3	Better inventory management for oil seal plate	Currently, two similar types of oil seal plates introduce confusion, so a two-bin system is deployed	A better understanding of the job
1.2	Barcode scanner timings	A new fixture was provided to reduce the time of impeller scanning	Reducing the time
2 & 2.2	Changing the layout of the LSCB machine	The position of the LSCB machine should be shifted closer to the St. 2	Reduction of motion and time
2 & 2.2	Eliminate the transporter	Product shifted manually from St. 2 to St. 2.2 by providing an extra operator	Reduction in WIP inventory time and unnecessary motion of the product
2 & 2.2	Tool holding arrangements	Tool holding arrangement provided at this station	Maintaining 5S activity
3	Providing a core lifter	A core lifter is used to carry the product from the LSCB machine to St. 3.1	Reducing the cycle time
3	Split St.3 into two parts	One more station and operator is employed to handle the heaviest station on the line. Some of the activities can be transferred to St. 3.2 and maybe automated further	Reduction of the cycle time that increases the output up to a great extent

Kaizen or Opportunity

These are the observations that need to be implemented to improve the current situation and improve productivity. Kaizen is a teamwork or activity in implementing a VSM tool where all cross-functional team associates and members are engaged in Kaizen identification (Maarof and Mahmud 2016; Dinesh et al. 2019). The well-intentioned Kaizen events can fix some problems but may not help much to boost the value stream's overall flow. Here, the identification of bottlenecks, stoppage, and wastage is important where the cycle time is marginally close to the takt time. Kaizen activities should be more focused on the bottleneck operation to allow the scope of improvement which can be seen in the end line product and productivity.

Identification of Kaizen

The following observations and decisions are made to create a future action plan, and the associated benefits are summarized in Table 5.

VSM Future State Map

A future state VSM is simply a projection of how the value stream looks in the upcoming time, in general, 3–6 months, depending on the nature of the organization. Future VSM shows if observed Kaizen is implemented, then what will be the process flow. In this case, the future state VSM is shown in Fig. 11.

Results and Discussion

The goal of the study was to identify opportunities through Kaizen assessment and simultaneously reduce cycle time using VSM. A suitable number of operators were deployed for the continuous flow process. After implementing Kaizen systematically and assigning an appropriate number of workers, productivity increased from 130 to 200 units/day, which is sufficient to meet the fluctuation in demand. Here, the number of operators increases, but the flow of material becomes smooth. For the current demand, i.e., 130 units, company saves 55.13% time of the total available time of the second shift, i.e., 6.5 h. Now the industry can handle takt time from 6 min (before) to 3.9 min (after applying VSM). The requirement of formulating a product family chart is negated since all models pass through the same process steps (Fig. 12).

A comparison is made based on the current and future state VSM, and the data is summed up in Table 6.

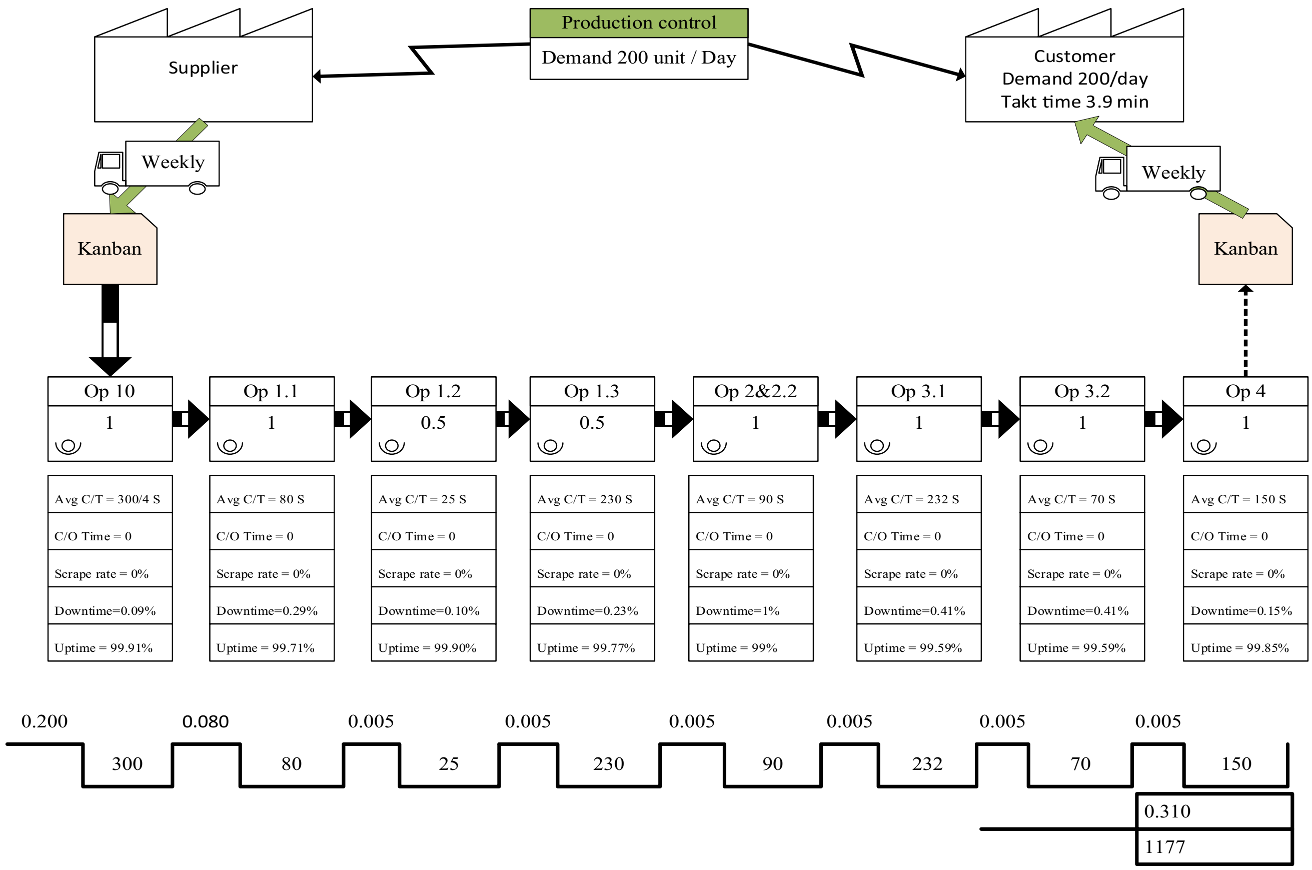


Fig. 11 Future state VSM

After splitting St. 3 into St. 3.1 and St. 3.2 and eliminating the transporter between pressure testing and the LSCB machine, the new modified layout is given in Fig. 13 with the optimum number of operators. The flow of process becomes smooth because the extra movement of operators between St. 1.1 to LSCB and St. 1.2 to 1.3 is eliminated.

The rotary of St. 1.3 is eliminated, and a new manual operator fixture is developed to hold the core. It saves approximately 80 s, leading to a reduction in cycle time and concurrently saving energy as initially the rotary was driven electrically. A pneumatic multi-spindle torque tool is provided for tightening more than one bolt simultaneously (Fig. 14).

Conclusion

The current study provides a systematic case study of enhancing output in an automotive manufacturing assembly line by implementing VSM as a lean tool. VSM shows the graphical overview of the flow of information and material by which one can illustrate and analyze the logic of a

Fig. 12 Productivity improvement measurement

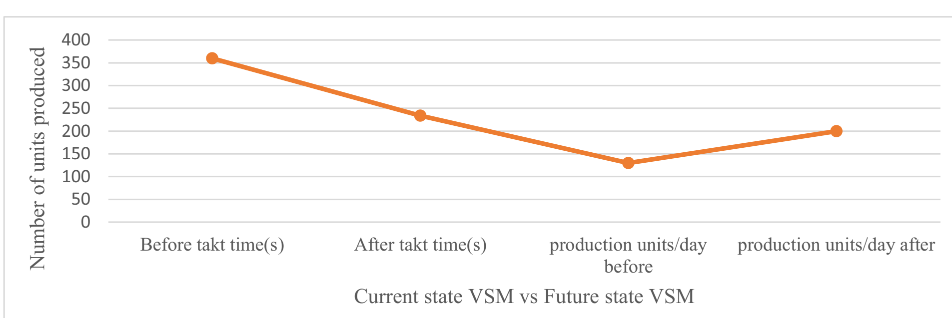


Table 6 Comparison of current and future VSM

S. No	Parameter	In current VSM	In future VSM
1	Total lead time	0.484 days	0.324 days
2	Value-added time	0.0153 days	0.0136 days
3	Non-value-added time	0.469 days	0.310 days
4	Value rate addition	3.27%	4.39%
5	Work-in-process	61	62
6	Takt time	6 min	3.9 min

production process (Oberhausen and Plapper 2015). It is observed that by appropriately implementing a lean tool like VSM, industries can leverage other lean methodologies concurrently. The empirical validation shows a reduction of the overall cycle time by 20.28% and a gain in the number of units produced by 46.16%. The results demonstrate that an increase in productivity is possible after careful assessment by eliminating waste (through VSM) and modifications in the layout and assigning an appropriate number of workers (through LB). The workload is evenly distributed after

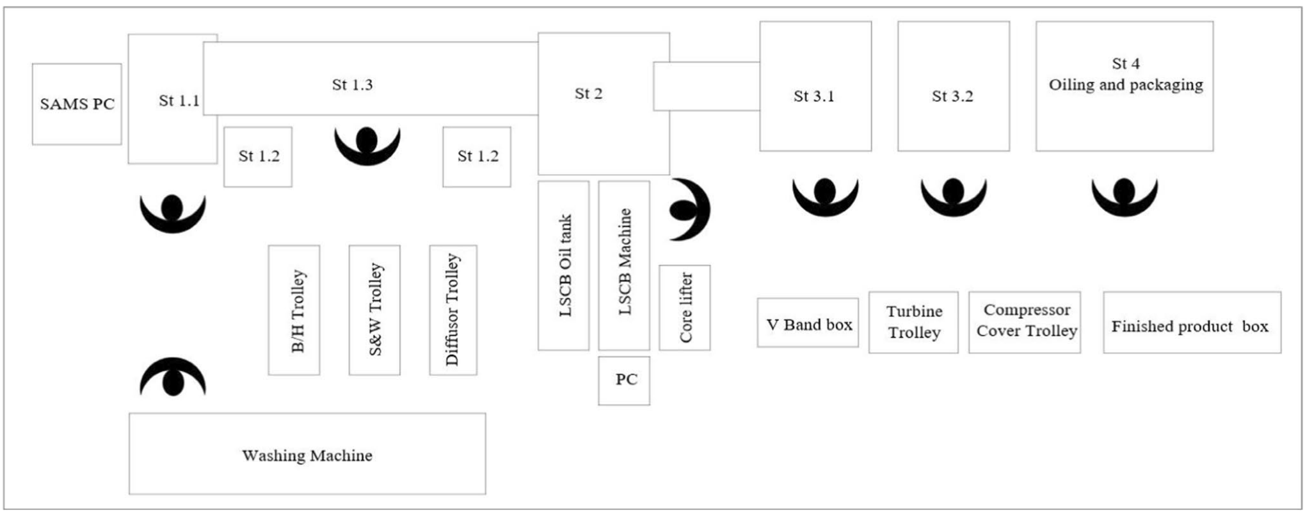
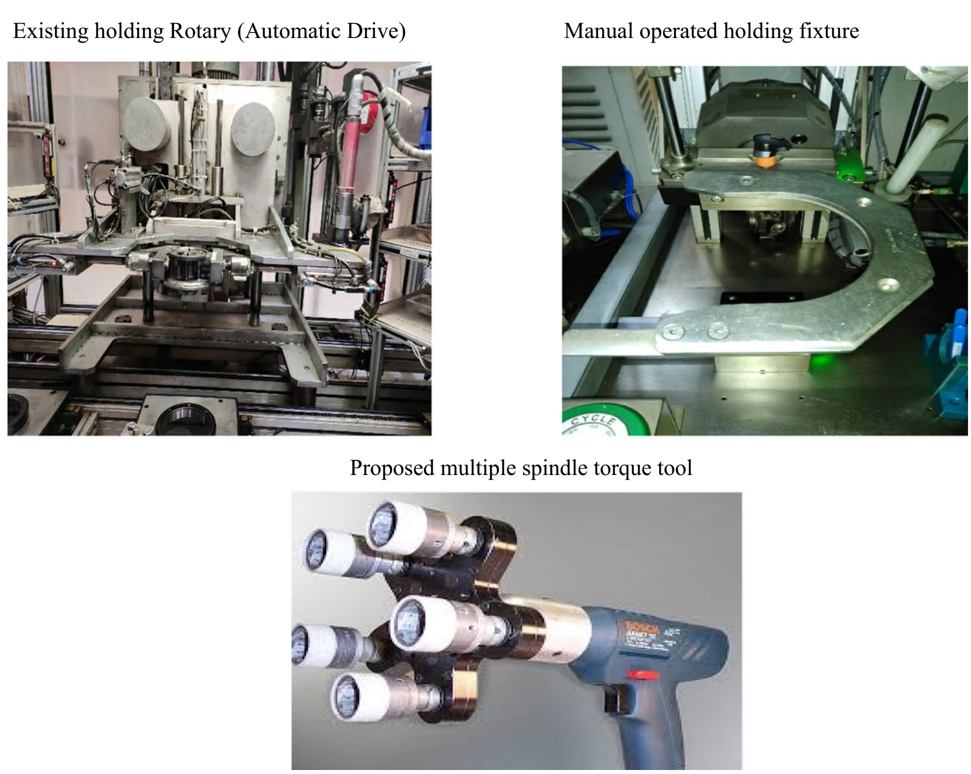


Fig. 13 Proposed layout of existing processes of the assembly line in the plant

Fig. 14 Existing V/S new job holding system



introducing new stations and eliminating previously present stations, automatically balancing the assembly line. VSM is used to track the flow of resources and develop continuous improvements in an organization, but the benefits depend on the improvement activities, i.e., Kaizens. The Kaizen events should be implemented to allow for considerable improvement in the overall cycle time, and the results are visible at the end of the line.

Limitations and Future Scope of Research

The current study focuses on an automotive component manufacturing industry; hence, the results are specific to the particular industry. Further extension and validation can be done for other automotive industries manufacturing similar components. The process layout and material flow analysis will change considerably in a service-based industry as these industries vary in nature and function. Thus, more lean tools need to be incorporated. The current study focuses on lean tools like VSM, LB, Kaizen, layout change, and 5S. More advanced techniques like industrial automation, Industry 4.0, and Industrial Internet of Things (IIoT) might bring further improvement strategies. Such techniques are not addressed and allow for future research possibilities.

There are several factors like communication gap between top management and shop floor employees, lack of motivation, poor reward system, inadequate training system, and resistance to change that lead to inefficient Kaizen implementation (Maarof and Mahmud 2016). Top management commitment, flexible policies, and clear corporate strategy are key factors to implementing Kaizen successfully (Imai 1986). At present, lean production has enabled global industrial production to attain a high level of efficiency and productivity.

The advantage of VSM is that it is applicable in the manufacturing sector, the healthcare sector, and the service sector to map the current scenario. VSM is a technique deployed on goods governing logic. Some services are organized with goods presiding logic. Generally, services consisting of a high amount of variability introduce a higher degree of involvement of workers. Thus, the implementation of the VSM methodology is difficult. In these cases, traditional mapping is helpful instead of VSM. Although VSM is used in many cases, it needs further exploration in various industries as a lean methodology to be a universal solution as enablers and barriers to every tool exist in the industry.

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Satyendra Kumar Sharma, methodology, writing — review and editing, and provide insights.

Data Availability Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Declarations

Conflict of Interest The authors declare no competing interests.

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