Assessment of Manufacturing Process Through Lean Manufacturing and Sustainability Indicators: Case Studies in Indian Perspective

Vikas Swarnakar, A. R. Singh and Anil Kr. Tiwari

Abstract Due to the government pressure and public awareness, industries are bound to incorporate sustainability in their manufacturing process. In this context, the concept of lean manufacturing and value stream mapping (VSM) process has been used widely in various manufacturing industries to minimize the waste in their production process. The objective of this study is to propose a conceptual model for the integration of VSM tool integrated with various sustainability indicators. The proposed model is capable to assess the manufacturing process into three sustainability dimensions such as economic, social, and environmental. This methodology was applied to two different manufacturing industries such as automotive component manufacturing organization and PVC pipe manufacturing organization, situated in India. The result demonstrated that the proposed methodology identified the areas of improvement after applying these integrated methodologies and clearly enabled the opportunities for improvements in both manufacturing organizations.

Keywords Lean manufacturing · Sustainability indicators · Manufacturing process · Value stream mapping

1 Introduction

The operation management frameworks have been developed to adopt the new changes in the market with certain changes in customer demands. During the twentieth century, the increase in demands for quality of products thus various management

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frameworks have come into the competitive market to fulfill the customer needs. This framework was developed based on the analysis of standard time, methods, and operations. In the end of the twentieth century, the demand of the quality product was in hike due to globalization, and resulted various manufacturing processes had been managed according to quality, delivery time, cost of the product, flexibility, reliability, and speed indicators [8]. Lean manufacturing approach is wieldy applied for the management of manufacturing process. The objective of lean manufacturing is to eliminate waste from the production process and enhance the operational improvement of the organization. The various improvements can be found after the successful implementation of the LM concept such as reduction in cycle time, waiting time, inventory level, number of employees; this can directly help in the improvement of quality, cost, and delivery time of the product. Ultimately, these improve customer satisfaction level of industry in the competitive market. This study introduces a new group of sustainability indicators integrated with three dimensions such as economic, social, and environmental key performance index (KPI), and these indicators are integrated with lean manufacturing tools VSM (lean KPIs) to develop a conceptual method for assessing sustainability of the manufacturing process.

2 Literature Review

2.1 Reviews on Adoption of Lean Manufacturing

Lean manufacturing (LM) is defined as a methodology which eliminates waste from manufacturing process through reduction in non-value-added activities and improves bottom-line results. Eatock et al. [4] defined that the lean manufacturing is a set of principles, procedures, methods which helps to reduce waste and improve the production process. The study highlighted the value stream mapping tool is a most powerful tool among the other lean tools and also stated that this tool provides a holistic view and is highly used in several organizations. Chen et al. [2] presented an implementation process of lean manufacturing in a factory with the help of a case study. Kuhlang et al. [9] proposed the concept of extended value stream mapping (EVSM). The EVSM consisted of transport indicators and allowed this for the development of future scenario for the improvement in manufacturing process. Dües et al. [3] analyzed the relation between green and lean manufacturing practices in the area of supply chain management (SCM).

2.2 Reviews on Sustainability Indicators

Sustainability can be defined as is the ability to maintain organization profit (expected by shareholders) in the manufacturing of goods or services without affecting the environment [6]. Hueting [7] explored that the environmental sustainability is an action which protects the essential environmental functions for future generation. Strezov et al. [11] elaborated that each sustainability dimension consisted of sustainability indicators which easily asses the sustainable performance of any organization. Faulkner and Badurdeen [6] developed a conceptual model of sustainable value stream mapping (Sus-VSM) integrated with various sustainability indicators. Brown et al. [1] applied the same model developed by Faulkner and Badurdeen [6] in three different manufacturing industries with a different process such as flow shop, job shop, and manufacturing cells. Roufechaei et al. [10] highlighted the concept of economic sustainability developed based on the ratio of investment and return as per expectation of shareholder. The study also stated that the use of economic indicators in value stream mapping tool contributes to the assessment of economic characteristics in their manufacturing process.

From the above review, there is a need to develop the method for assessment of the manufacturing process. In this work, our aim is to integrating the new group of sustainability indicators (economic, social, and environmental) into lean manufacturing tools (VSM) to assess the manufacturing process of Indian manufacturing industry.

3 Methodology

The methodology used in this study is clearly presented with the help of flow diagram and shown in Fig. 1. In this diagram, the first step is method is separated into two stages. The first stage needs to review the literature regarding sustainability indicators, and in the second stage we need to categorize the group of sustainability indicators that compose the assessment method used to assessing the sustainable

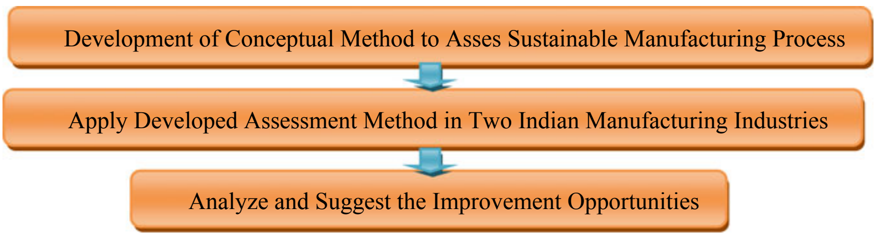

Fig. 1 Applied methodology

manufacturing process. The objective of this first step is to define a new group of sustainability indicators which integrated with three dimensions such as economic, social, and environmental, and these indicators are integrated with lean manufacturing tools (VSM) to develop a conceptual method for assessing sustainability in the manufacturing process. This concept was developed based on valuation models presented by Kuhlang et al. [9].

The sustainability indicators are identified with experts' opinion and literature review from 2009 to 2017 searched by the following keywords: sustainability indicators, lean manufacturing, value stream mapping. In step 2, need to apply the assessment method in two Indian manufacturing industries. The data were collected through direct observation of the shop floor and detailed discussion with senior management, employees, and operators.

4 Development of a Conceptual Method to Assess the Sustainability in the Manufacturing Process

The conceptual method for assessing sustainability in the manufacturing process through the integration of sustainability indicators with VSM tool was developed. In this context, new group of sustainability indicators was developed based on triple bottom line (TBL) concept and various reviewed literatures.

4.1 Development of Key Performance Index Based on TBL Concept

The three KPIs have been developed according to Eccles et al. [5], and the study stated that both social and environmental dimensions are directly associated with expected payback period. In India, most of the manufacturing industries do not have exact knowledge about suitable metrics for measuring the cost-benefits of sustainability. The conceptual method is proposed to integrate lean manufacturing and sustainability indicators to assess the manufacturing process. In this study, a new group of KPIs has been developed through the literature review and experts' opinion. The experts are having more than 15 years of industrial experience. In this context, each manufacturing operation is calculated using various formulas which are clearly presented in Table 1. In this study, six sustainability indicators have been considered and all are having equal weights and importance.

Table 1 Various KPIs used in lean manufacturing tool VSM

Dimension	Field/area	Sustainability indicators	Formula used for calculation
Economic	Cost management	Operational cost	OC (Rs.) = cycle time (labor cost + management cost + depreciation cost)
		Effective cost	Operational cost/overall equipment effectiveness
Social	Satisfaction level	Absent rate	Abs (%) = total absentee time (in h)/total working time (in h)
		Accident rate	Total no. of accidents/total employees
Environmental	Quality and health	Electric consumption	Calculate based on predefined reference
	Consumption	Water consumption	Calculate based on predefined reference

5 Case Study

The pilot test was performed in two Indian manufacturing organizations. The first test was performed in one automotive component manufacturing organization named as ABC situated in Tamil Nadu, India, and second was in polyvinyl chloride (PVC) pipe manufacturing organization named as XYZ situated in Chhattisgarh, India. Due to non-disclosure agreement terms, we cannot mention the exact name of the companies. The conceptual method was applied in both organizations that have the high maturity of both lean and sustainable practices. Both manufacturing processes are characterized as flow shop and manufacturing high volume and low variety products. The data are as follows.

5.1 Pilot Test at an Automotive Component Manufacturing Organization

The customer demand for case product was 8000 pieces per day. The total available time was 480 min/day, and actual production time was 420 min/day. Thus, Takt time can be calculated as 9.45″ per piece. The manufacturing process is shown in Fig. 2. The data have been collected from shop floor observation and proper meeting with workers, and management persons. The VSM is developed and calculated with the

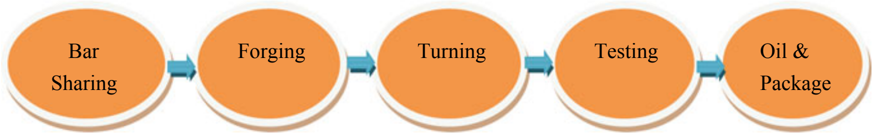

Fig. 2 Automotive component manufacturing process

integration of sustainability indicators and shown in Fig. 3. The Takt time was calculated as 10.8″ (process cycle time is less than or equal to Takt time) that meets the customer demand and is considered as sustainable. The high inventory level in the process leads to high lead time (16.2 days). This VSM integrated with economic, social, and environmental indicators. The reference value is necessary to calculate the bottleneck operation in manufacturing process and obtained through an interview with production and human resources department peoples. In this study, two sustainability indicators are considered under economic dimensions such as operational cost and effective cost. The operational cost is calculated for each process, and it observed the highest relative cost of 29.85% for forging operation in the manufacturing process and is considered as bottleneck operation. The effective cost calculated and observed the highest relative cost of 24.77% for testing operation in all process and thus is also considered as bottleneck operation.

The two sustainability indicators are considered under social dimension such as absent rate and accident rate. The absent rate has calculated and identified highest relative rate of 33.33% for bar shearing operation, and accident rate has observed high relative rate of 85.71% for forging operation in all manufacturing processes. In an analysis of environmental dimension, two sustainability indicators are considered as electric consumption and water consumption. The high electric consumption has been observed (relative cost of 20.22%) in forging operation and is considered as

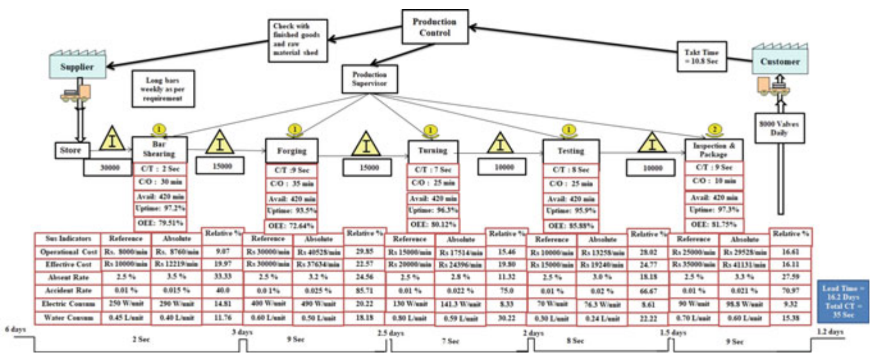

Fig. 3 Sustainability indicators in VSM applied in automotive component manufacturing organization

bottleneck operation. The high water consumption has been observed (relative cost of 30.22%) in turning operation, and this process is also considered as a bottleneck operation.

5.2 Pilot Test at PVC Pipe Manufacturing Organization

The customer demand for case product was 15,000 pieces per day. The total available time was 480 min/day, and actual production time was 420 min/day. Thus, Takt time can be calculated as 5.76″ per piece. The manufacturing process is shown in Fig. 4. The data have been collected from shop floor observation and proper meeting with workers, and management persons. The VSM is developed and calculated with integration of sustainability indicators and shown in Fig. 5. The Takt time was calculated as 5.76″ (process cycle time is less than or equal to Takt time) that meets the customer demand and is considered as sustainable. The high inventory level in the process leads to high lead time (18.2 days). This VSM integrated with economic, social, and environmental indicators. The reference value is necessary to calculate the bottleneck operation in manufacturing process and obtained through an interview

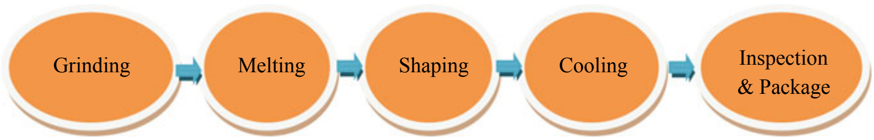

Fig. 4 PVC pipe manufacturing process

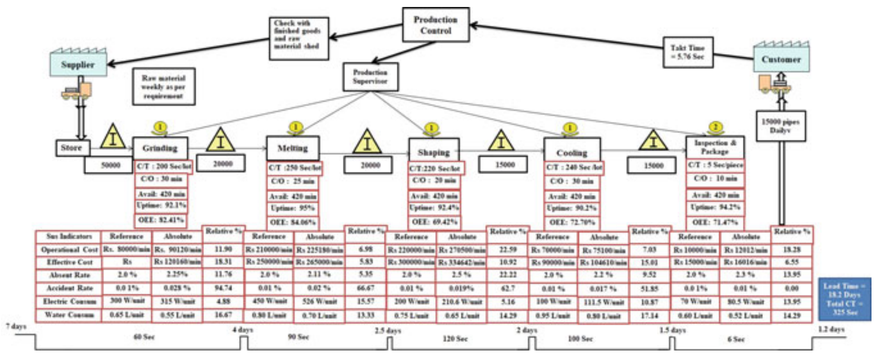

Fig. 5 Sustainability indicators in VSM applied in PVC pipe manufacturing organization

with production and human resources department peoples. In this study, two sustainability indicators are considered under economic dimensions such as operational cost and effective cost. The operational cost is calculated for each process, and it observed the highest relative cost of 22.59% for shaping operation in the manufacturing process and is considered as bottleneck operation. The effective cost calculated and observed the highest relative cost of 18.31% for grinding operation in all processes and thus is also considered as bottleneck operation.

The two sustainability indicators are considered under social dimension such as absent rate and accident rate. The absent rate has calculated and identified highest relative rate of 22.22% for shaping operation, and accident rate has observed high relative rate of 94.74% for grinding operation in all manufacturing processes. In an analysis of environmental dimension, two sustainability indicators are considered as electric consumption and water consumption. The high electric consumption has been observed (relative cost of 15.57%) in melting operation and is considered as bottleneck operation. The high water consumption has been observed (relative cost of 17.14%) in cooling operation, and this process is also considered as bottleneck operation.

5.3 *Opportunity for Improvements Observed in Case Studies*

The result has been obtained from the case study and summarized in Table 2. It can be clearly observed that the developed conceptual method for manufacturing process assessment is applicable in these case studies. It can be also observed that the various bottleneck operations are fluctuated according to sustainability dimension. Thus, the improvements can be developed with the different bottleneck operations. The various improvement actions have been identified and suggested for further improvements in manufacturing process and shown in Table 3.

Table 2 Summarized result for the assessment of manufacturing process

Case	Economic dimension (bottleneck operations)		Social dimension (bottleneck operations)		Environmental dimension (bottleneck operations)	
	Operational cost	Effective cost	Absent rate	Accident rate	Electric consumption	Water consumption
1	Forging	Testing	Bar shearing	Forging	Forging	Turing
2	Shaping	Grinding	Shaping	Grinding	Melting	Cooling

Table 3 Opportunities for improvements

S. no.	Action taken	Case	Dimension	Sustainability indicators	Opportunities for improvement
1	1	1;2	Economic	Overall equipment effectiveness	To improve the OEE% need to improve three key metrics which are availability; performance; and quality. The availability can be improved with the use of total productive maintenance tools and techniques; performance can be improved with the use of setup time reduction tools; quality can be enhanced with the use of reducing defects and eliminate waste from the process
2	2	1;2	Economic	Inventory	The inventory can be reduced using Kanban techniques
3	3	1;2	Economic	Operational cost	Operational cost can be reduced by reducing the cycle time of the process using lean Six Sigma tools which reduce the waste and reduce the variation in customer demands
4	4	1;2	Economic	Effective cost	To reduce the effective cost need to improve OEE% and reduce the operational cost using above technique
5	5	1;2	Social	Absent rate	To reduce the absent rate need to develop environment-friendly work environment and adopt some employee motivation technique
6	6	1;2	Social	Accident rate	To reduce the accident rate need to develop safety departments and organize safety program and time-to-time proper training is required related safety precautions. Also, adopt structured safety rules in the organization
7	7	1;2	Environmental	Electric consumption	To reduce the electric consumption in forging and melting process with change the machine parameter using discrete event simulation model and DOE technique
8	8	1;2	Environmental	Water consumption	To reduce the consumption of water using filtration techniques and reuse of water which is used in cooling and turning operation

6 Conclusion

The concept of integrating lean manufacturing tool, value stream mapping (VSM), with sustainability indicators to assess the manufacturing process has been recently discussed in the literature by various authors. However, development of a conceptual model for the integration of VSM tools with various sustainability indicators in the assessment of the manufacturing process that efficiently contributing the increased level of sustainability in any manufacturing process is in the initial stage. Thus, the main objective of this study is to discuss the obtained result and improvements identified in the two industrial case studies related to the assessment of manufacturing process through integration of VSM and sustainability indicators. The case studies are presented for assisting the new direction for improvement and future research in the field of lean manufacturing (LM) and sustainability. This methodology brings the new group of sustainability indicators under the three dimensions that are economic; social; and environmental. Two sustainability indicators have been considered under each dimension through developed assessment mode and the reviewed literature on sustainability indicators. The opportunities for improvements have been identified and presented clearly. After successful implementation of actions, various improvements can be observed toward the assessment of manufacturing process.

The study has been pilot tested in two manufacturing organizations situated in India with few sustainability indicators. In the future, it can be tested in more than two manufacturing organizations with a new group of sustainability indicators to assess the manufacturing process.

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