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Research Article

Kaizen Selection for Continuous Improvement through VSM-Fuzzy-TOPSIS in Small-Scale Enterprises: An Indian Case Study

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In the era of cut throat competitive market, Indian industries are under tremendous pressure to continuously reduce the cost and improve product quality. The main objective of this research paper is to provide a road map for investigating the opportunities to reduce cost and improve productivity and quality in the existing production system through the application of Lean-Kaizen concept using value stream mapping (VSM) tool at shop floor of an Indian Small-Scale Enterprise (SSE). On the basis of collected data from the selected industry, a current state map was made. After analysis, the current state map was modified to develop a future state map. By comparing current and future state map, the gap areas were identified and takt time (TT) was calculated considering actual market demand. To overcome the gap between current state map and future state map and to synchronize cycle time of each station with talk time, Kaizen event (KE) was proposed. Fuzzy technology for order preference by similarity to ideal solution (TOPSIS) was applied to prioritize and select the appropriate KE for optimized performance level. After analysis of data obtained after application of the Lean-Kaizen concept, the final improvements in terms of improved productivity (57.15%) and reduced lead time (69.47%), reduced cost (65.61%), and station cycle time (75.25%) were recorded. Through the case study drawn from realistic situations of the industry, the authors highlight that implementation of Lean-Kaizen using VSM and fuzzy TOPSIS provides improvement opportunities across the organization. The findings can inspire the SSEs to adopt the Lean-Kaizen concept for optimizing continuous improvement opportunities in their production industry. This study offers the researchers and practitioners a good example for understanding, selecting, and performing KE program. They can even attain more improvement in various areas by establishing or improving these KE programs.

1. Introduction

In order to meet real world of competitive situations like producing products at the lowest cost, Indian SSEs are now ready to adopt lean tools and techniques for minimizing product cost, eliminating waste, and reducing delivery time [1]. Due to limited budget and financial conditions, some of SSEs are not able to afford any improvement program and lack many lean benefits. Sometimes, the improvement program is not organized in an effective way and ultimately hits the routine activities so badly that the organization does not even think to rearrange it. This study may encourage such SSEs to organize continuous improvement programs through application of "Lean-Kaizen concept" so that optimum benefits of the event can be achieved.

Lean-Kaizen means removal of non-value-added (VA) activities (wastes) by adopting small improvements [2]. The collection of lean tools and techniques, namely, value stream mapping (VSM), poka-yoke, standardization, visual control, and kanban cellular manufacturing, is called lean building block [3, 4]. Henry Ford witnessed that standardization and innovation are equally essential for any organization. He suggested that LM and Kaizen tools are needed to identify opportunity in order to reduce wastes and improve

Figure 1: Spindle kick disco model.

overall performance. Grunberg [5] notifies that it is most important what to and how to improve in process. Marvel and Standridge [6] suggest that the selection of inappropriate lean tool causes various disruptions in the process of lean implementation, which influence the expected outcomes and reduced employee confidence of organization, which results in increase in various costs, wastes, and production time.

In today's real-world situation, lean tool fitness in particular organization heavily depends on a particular manufacturing process of the organization. The decision making is one of the most critical issue before or while selecting appropriate lean tools and techniques. Many methods have been established and used for solving diverse kinds of multicriteria decision making (MCDM) problems. Chen [7] suggested fuzzy technology for order preference by similarity to ideal solution (TOPSIS), which helps decision makers to know the complete evaluation process and offers a systematic, accurate, and effective decision support tool. It helps to resolve multicriteria decision making difficulties under vagueness such as

$$A = \{x, \mu_A(x)\}, \quad \text{where } x \in X \tag{1}$$

where $\mu_A(x)$ is membership function of A and is defined in universe of course [0, 1].

In general, two types of fuzzy numbers, triangular and trapezoidal, are used, in which triangular fuzzy number (TFN) is commonly used for computation efficient information in fuzzy environment.

$$\mu_A(x) = \begin{cases} 0 & \text{for } x < l \\ \dfrac{x-l}{m-l} & \text{for } l \le x \le m, \\ \dfrac{u-x}{x-m} & \text{for } m \le x \le u \\ 1 & \text{for } x > u \end{cases} \tag{2}$$

where l, m, and u are the parameters showing the least permissible value, the most promising value, and the largest possible value. The fuzzy event is shown by l<m<u (Figure 1), where m shows the maximum relevance degree at m and null outside the internal [l, u].

The algebraic operations of two TFNs, $M_1\ (l_1, m_1, u_1)$ and $M_2\ (l_2, m_2, u_2)$, as given in Figure 2 are performed as

$$\begin{aligned} M_1 + M_2 &= \{(l_1 + m_1 + u_1) + (l_2 + m_2 + u_2)\} \\ &= \{(l_1 + l_2), (m_1 + m_2), (u_1 + u_2)\} \\ M_1 \times M_2 &= (l_1, m_1, u_1) \times (l_2, m_2, u_2) \\ &= \{(l_1 \times l_2), (m_1 \times m_2), (u_1 \times u_2)\} \end{aligned} \tag{3}$$

Distance calculations for two TFNs are

$$d(M1, M2) = \sqrt{\frac{1}{3\{(l_1 - l_2), (m_1 - m_2) + (u_1 - u_2)\}}} \tag{4}$$

Based on the criteria of benefit and cost categories, the normalization of the fuzzy numbers using (Chen, 2000) is as follows.

For benefit criteria,

$$r_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right), \quad j \in B, \tag{5}$$

where

$$u_j^+ = \max_i u_{ij} \tag{6}$$

For cost criteria,

$$r_{ij} = \left(\frac{l_j^-}{l_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{u_{ij}}\right), \quad j \in C, \tag{7}$$

where

$$l_j^- = \min_i l_{ij} \tag{8}$$

Today, many Indian SSEs are still deprived of many lean benefits because Lean-Kaizen is still unfamiliar to employees in most of the Indian SSEs. The goal of this research paper is to deliver a road map for examining the opportunities to reduce cost and improve productivity and quality in the existing production system by implementing Lean-Kaizen concept with VSM tool of an Indian SSE. This paper demonstrates a case study in order to find continuous improvement opportunities in the process and practices of an Indian SSE situated at NCR (noncapital region). Based on the collected information, a current state map (CSM) was made, which stated the current working condition of the organization. The calculated TT pointed out those processes that had station cycle time (CT) more than TT. A future state map (FSM) was prepared by modifying the CSM in which supermarket pull system and continuous flow processing were introduced at workstations to control the production of the process. Gap areas were identified by comparing CSM and FSM of the manufacturing. To synchronize CT of each station with talk time, various lean tools and techniques were used. Fuzzy-TOPSIS approach was used to rank and select the proposed Kaizen event. After implementation, the collected data was investigated and conclusions are made.

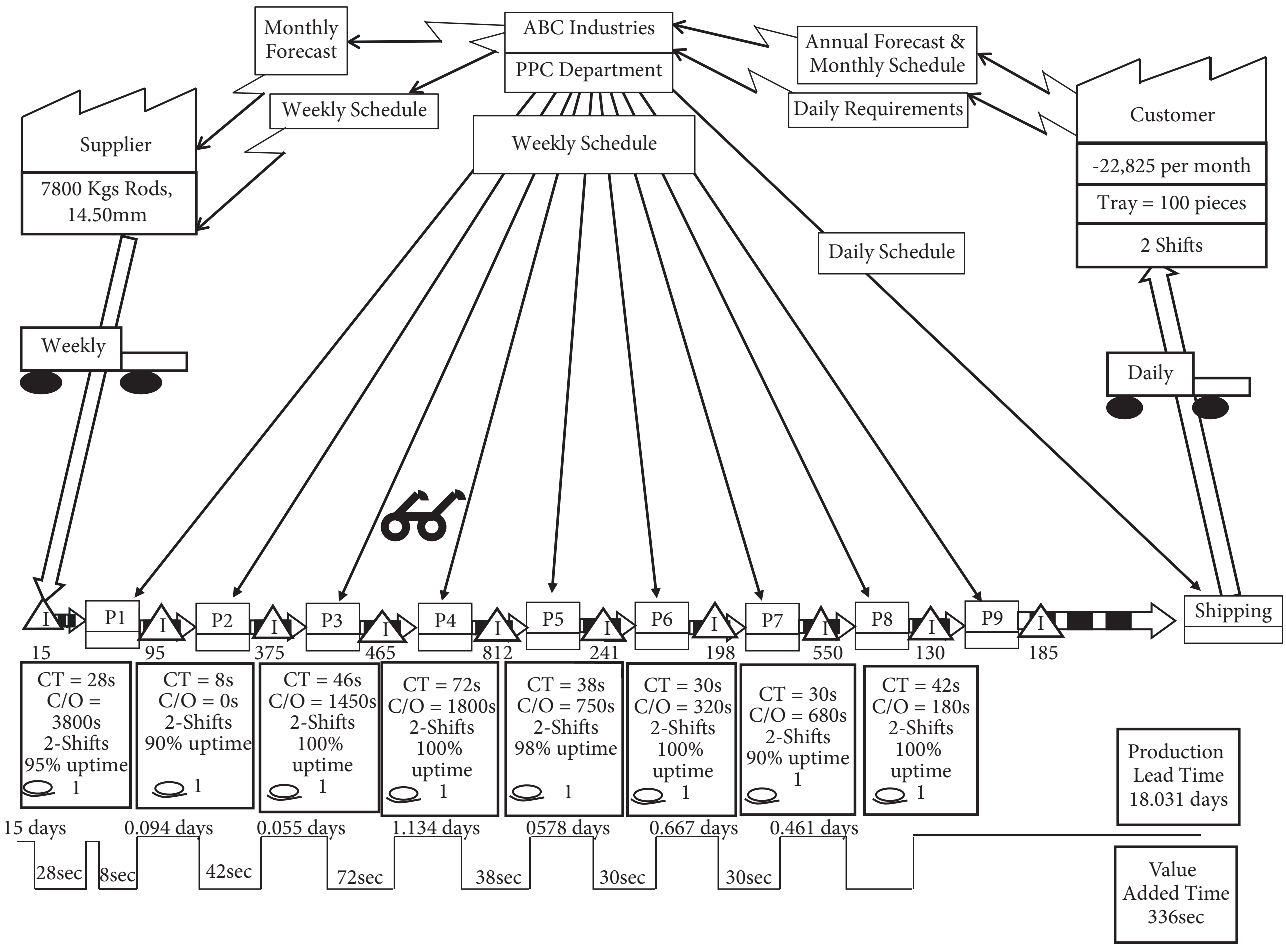

Figure 2: Current VSM.

This paper contributes to two dimensions. First, it highlights the restrictions to implement Lean-Kaizen approach in Indian industrial environment. Second, it offers a roadmap for applying lean concept in Indian SSE in order to achieve opportunities of improvement existing in the routine production of products on the shop floor, which keeps the organizations on the right track towards achieving their goals.

2. Literature Review

2.1. Lean Manufacturing, VSM, and Kaizen. Lean manufacturing (LM) is a process or procedure that stresses accumulative work efficiency and minimizing processes expenses [12–16]. The success of LM implementation hinges on proper skills, employee contribution, and training and top management commitment [17, 18]. Kaizen progresses uniquely inside each organization [19]. Bateman [20] notified that lean implementation paves way to progress quality of the processes. Bhuiyan and Baghel [21] demonstrated that continuous improvement program can remove the waste of production and quality of the product. Scyoc [22] assessed various quality tools and techniques for improving process safety and work team. Glover et al. [23] reported that holding the consequences of KEs is challenging over time for many organizations. Suarez-Barraza et al. [24] noticed that three methods (5S, Process mapping and Gemba Kaizen workshops) influenced directly the product, processes, and systems. Lean practices improve the quality in public services [25]. Karim and Arif-Uz-Zaman [26] projected a procedure that helps in systematic improvement of performance of organization. Arya and Choudhary [27] concluded that lean improves product quality and production efficiency. VSM can reduce inventory levels, reduce system waste, minimize resources, and improve the system and performance of the organization [28–37].

2.2. Fuzzy-TOPSIS. Many authors have applied fuzzy techniques for various purposes: to select the location of furniture factories [38], to select robot by seeing both subjective and objective criteria [39, 40], and to choose suitable maintenance strategy [41]. Singh et al. [42] used fuzzy logic to develop efficient measurement lean index to evaluate leanness of manufacturing firm. Kumar et al. [43] used fuzzy-TOPSIS and provided framework to evaluate lean performance of any organization. References [44–46] used fuzzy approach to evaluate leanness of the manufacturing organization. Vidyadhar et al. [47] applied fuzzy logic and developed a conceptual model to evaluate leanness in SMEs. Ravikumar

Table 1: Research contribution for integrated VSM with fuzzy technique.

Research	Tools Used	Contribution
Achanga et al. [8]	Fuzzy-logic advisory system	A decision support tool used for lean manufacturing implementation at the early implementation stage in small-medium-sized enterprises (SMEs)
Wang and Chan [9]	Hierarchical fuzzy-TOPSIS approach	Measure areas of improvements when implementing green supply chain management (GSCM)
Vahdani et al. [10]	Fuzzy-TOPSIS approach with FMEA (failure mode and effect analysis)	Evaluate and overcome the inadequacy of the traditional FMEA technique and rank the group belief structure model
Mohanraj et al. [11]	VSM with fuzzy quality function deployment (QFD)	Evaluate scientific prioritization of improvement proposals to develop leanness

et al. [48] used fuzzy-TOPSIS method to measure the effect of critical success factors of lean in six Indian manufacturing industries. Agrawal et al. [49] identified twelve lean critical success factors and applied fuzzy-TOPSIS technique in five Indian electronics industries to prioritize them. The study concluded that four factors, namely, resource management, top management awareness, contracts terms and conditions, and economic factors, are most important, while process abilities and skilled workers are the smallest important factors in success of lean implementation. The various research contributions are also discussed in Table 1.

2.3. Issues of Lean Manufacturing and Kaizen Implementation. In today's competitive market, SSEs across the globe are seeking continuous improvement opportunities to increase their productivity and quality of product at lowest cost and Indian industries are no exception. In order to meet such requirements, Indian SSEs are adopting lean principles and methodologies in their processes and practices. The benefits of lean adoption for waste elimination are well documented in the literature [50, 51]. Large-Scale Enterprises (LSEs) use lean practices more than SSEs [52–55]. In the study of extensive literature review, it is perceived that, even after a good understanding of lean tools and techniques, the practical application of VSM in Indian SSEs is found feeble. Thus, the adoption of Lean-Kaizen concept can help organizations to find continuous improvement chances for eliminating waste in order to achieve competitive advantage and sustainable growth.

From the extent of literature, it is found that application of VSM to implement Lean-Kaizen concept through Kaizen event in SSEs is found feeble. The selection of Kaizen event using fuzzy-TOPSIS approach is proposed to optimize the lean benefits at all levels of organization.

3. Research Methodology

The case study is conducted in an Indian SSE named ABC Enterprises, situated in NCR (national capital region). The industry is manufacturing many automobile parts such as spindle kick disco model (SKDM, Figure 1), Roller bolt, and Sleeve. The SSE contains a total of 170 machineries generating 1250 crores Indian rupees turnover per annum. A total of 350 employees including supervisors, workers, and managers are working in two shifts of 8 hours. The data like CT, change over time (C/O), shifts, lead time and VA time, customer requirements, product transportation, and work-in-process are collected from production planning and control (PPC) and other departments by taking personal visit to the selected industry. The process symbols are used to prepare the CSM and FSM and gap areas/waste is identified. The fuzzy-TOPSIS approach is used to take decision for selecting suitable Kaizen events that optimize the performance level of the organization. Before and after Kaizen events, the collected data are compared to analyze results.

4. Current State Map

Based on data collected, A CSM (Figure 2) is prepared, in which monthly order for raw material and weekly shipment to customer are drawn. The process stages include nine processes: P1, cutting; P2, deburring; P3, hot forging; P4, CNC; P5, milling; P6, shot blasting; P7, OD grinding; P8, plating, P9, packing and shipping. The PPC department orders supplier for raw material monthly and consignment reaches every week at the industry. The production lead time and VA time are calculated as 18.031 days and 336 seconds, respectively. Process P5 reported high CT (72 seconds) and created bottleneck at P5, milling, due to high work-in-process and rejections.

5. Future State Map

The CSM is analyzed and modified using steps mentioned in Kumar et al. (2017b) for preparing FSM (Figure 3) for identifying waste.

The industry works in two shifts (8 hours each) in order to fulfill average customer demand of 22825 pieces/month within 25 days in a month. From available working time/day (50,400 seconds), the TT will be 55.20 seconds/piece (available working time/customer demand). The calculated TT shows that the industry is fixed to produce each workpiece in every 55.20 seconds to encounter the demand of the customer. As the customer demand varies unsteadily, the selected industry chooses to start a two-day supermarket holding inventory of finished goods for customer. The size of kanban is selected as "100 pieces." From Figure 4, the CT of P5 is 72 seconds (more than TT). The CT of P3 to P7 and P9 are

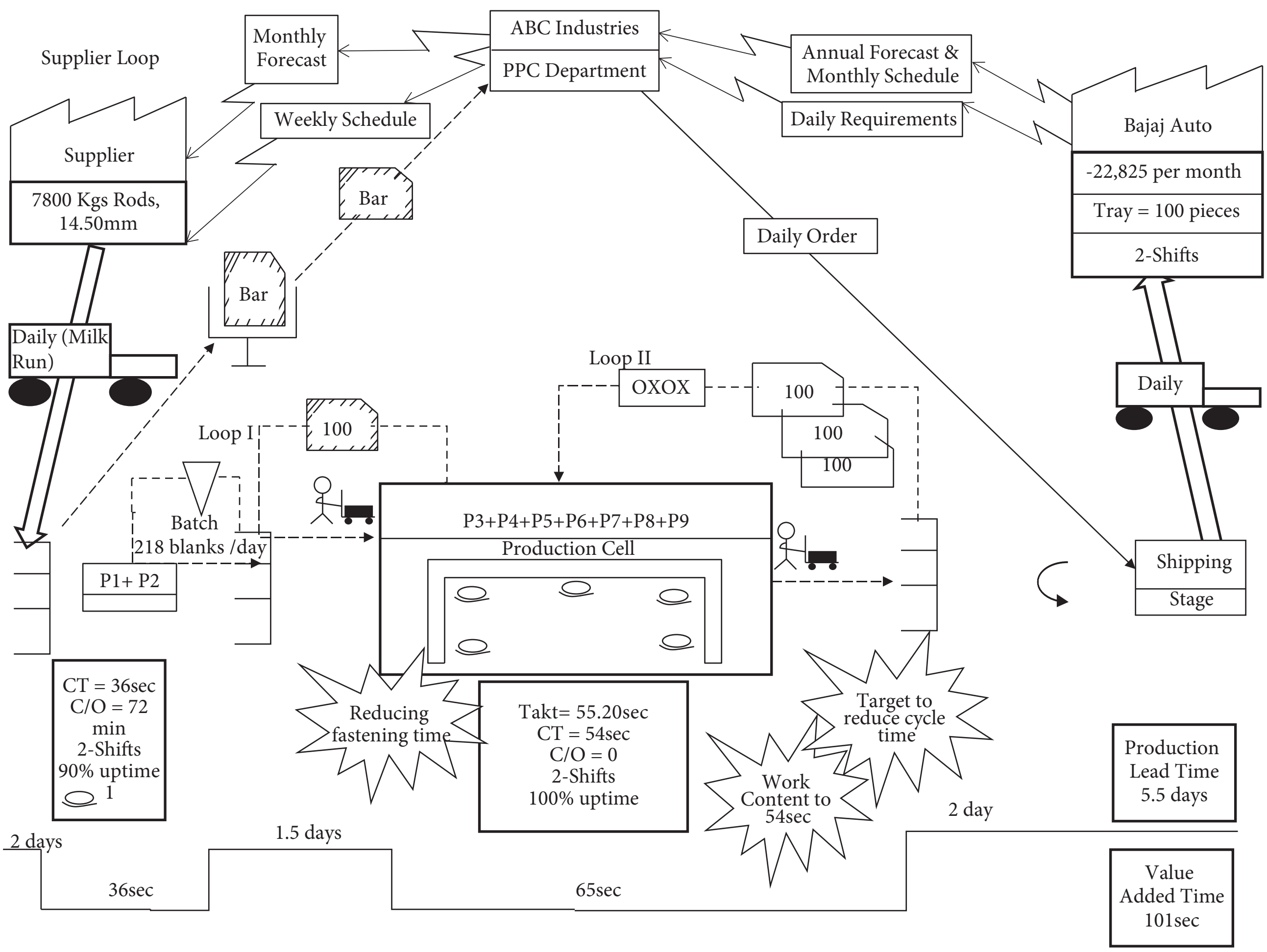

Figure 3: Future VSM.

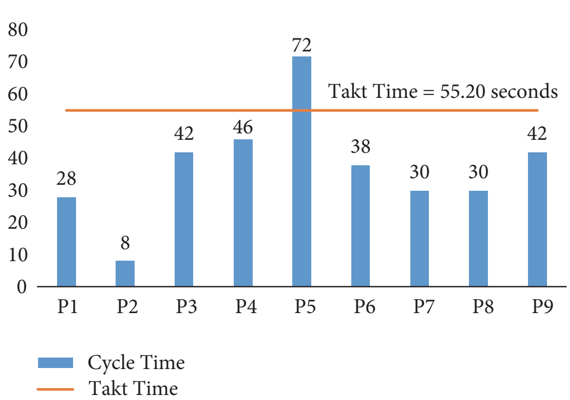

Figure 4: Cycle time and takt time for the processes.

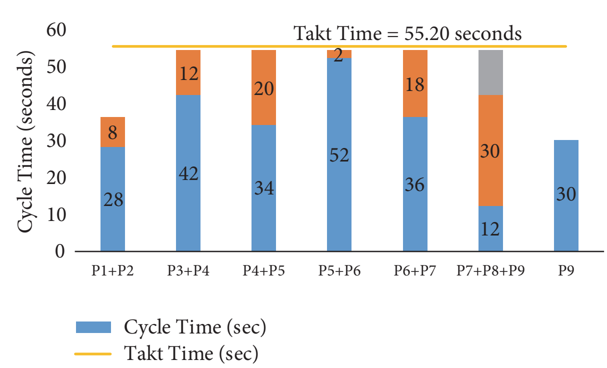

Figure 5: Cycle time with continuous flow.

very close and thus show a continuous flow process, so these processes can be shifted into one cell named "Production Cell" (Figure 5). However, the CT of P2 is small and distant from TT and thus can easily link with P1 to form a batch operation in order to keep the pace of the process.

In order to avoid difficulties in raw material inventories in the current situation, the selected industry generates two-day supermarket for raw material which ensures raw material availability and helps in scheduling the production of blanks. The industry introduces an internal kanban and a milk-run delivery system for raw material to eliminate 90% of raw material inventory. Another supermarket of capacity of 1.5 days is introduced in order to fill requirement of 218 blanks per day.

Table 2: Proposed KEs for identified gap areas/waste.

Identified gap area/waste	Proposed KEs
Chattering/tool marks and difficulties in fastening of workpiece	KE-1: training to operator/operator change KE-2: fixture design change with snap fastening KE-3: machine maintenance program for vibration reductions

As batching is difficult in production cell, a load leveling box is introduced (Figure 3). The pitch (5520 seconds/tray) is calculated, which means that each 100-piece tray will be moved on or after every 5520 seconds from one process to another.

The defect and inventory were identified as waste in the production line. The data analysis of machine downtime summary and defect wise rejection report that the main difficulties such as chattering mark and complications in fastening of SKDM are observed, which consequently increases the inventory level at P5. These difficulties of SKDM require to be eliminated.

6. Identifying Possibilities of Continuous Improvement

6.1. Selected Process and Proposed KEs. The milling process (P5) is performed to produce a slot into the shank of the workpiece in order to fulfill the (fitment) requirement of the customer. The screw type fixture is mounted on the milling table that grips the workpiece firmly. The clockwise/anticlockwise rotation of round screw handle is used to move the slide towards rotating cutter, which gradually produces slot on the workpiece.

As the objective of the Lean-Kaizen concept is to eliminate waste continuously through small-small improvements, the comparison of CSM and FSM was made and gap areas were identified. Various lean tools and techniques can be applied to bridge the gap between CSM and FSM. The change from the CSM to FSM may disclose many KEs. In the present study, the P5 process's activities were explored for identifying solution of existing problem by brainstorming process. Thus, a fuzzy condition was recorded as all KEs were based on five criteria: lean practices, customer complaint/communication, in-house quality practices, past experience, and tool room participation. Three KEs (to be implemented at process P5) were proposed in order to eliminate waste/gap areas (Table 2), but due to the limited budget and financial conditions, the industry can bear the expense of any of appropriate KEs, which would give optimum benefits at all levels of organization. In order to select one suitable KE, fuzzy-TOPSIS technique was used for ranking and evaluation of KEs performance.

6.2. Application of Fuzzy-TOPSIS. In order to assess the performance of proposed KEs, three alternatives (KE1, KE2, and KE3) and five criteria (C1, lean practices; C2, customer complaint/communication; C3, in-house quality practices; C4, past experience; and C5, tool room participation) were used to apply fuzzy-TOSIS approach on the basis of steps given in Kumar et al.'s work [43]. The evaluation of each Kaizen event to achieve goal of waste elimination/removal is presented in Figure 6.

Table 3: Weights and alternatives with fuzzy numbers.

Alternatives	Weight	Fuzzy number
Very low (VL)	Very poor (VP)	(1,1,3)
Low (L)	Poor (P)	(1,3,5)
Medium (M)	Fair (F)	(3,5,7)
High (H)	Good (G)	(5,7,9)
Very high (VH)	Very good (VG)	(7,9,9)

Table 4: Weighted criteria for three experts.

Decision makers	C_1	C_2	C_3	C_4	C_5
M1	H(5,7,9)	H(5,7,9)	VH(7,9,9)	H(5,7,9)	H(5,7,9)
M2	M(3,5,7)	M(3,5,7)	H(3,7,9)	L(1,3,5)	M(3,5,7)
M3	L(1,3,5)	H(5,7,9)	L(1,3,5)	L(1,3,9)	M(3,5,7)

Three decision makers (experts) M1, M2, and M3 were selected to submit their valuations of criteria importance weights and Kaizen performance rating against the goal of the selected organization. Fuzzy approach of triangular fuzzy numbers (TFN) is used to capture vagueness in evaluation of criteria weights as well as Kaizen performance. The five-point linguistic scale and the corresponding TFNs to evaluate the weight and alternatives are given in Table 3. The importance weight criteria given by the decision makers are provided in Table 4 and rating of Kaizen events based on personal valuation of the three decision makers is presented in Table 5 (average fuzzy rating, normalized fuzzy rating, and weighted normalized fuzzy rating). The linguistic variables, aggregate weight criteria, and the aggregate fuzzy rating of each KE are calculated.

Table 6 shows the FNIS and FPIS values with respect to each criterion. The calculated closeness coefficient (CC_i) for each KE and the comparison of closeness coefficients are given in Table 7. In this way, KE-2 was selected to be performed at P5.

7. Result and Discussion

7.1. Performing KE. The authors visited the workstation (P5) where a screw mounted fixture (design) was observed for performing milling operation of one workpiece at a time and tightening and loosing of SKDM were done by the lever and screw arrangement. This task was found to be time-consuming and tedious for the operators. Moreover, it was also reported for high possibility of accidents during the process and required skilled operator at P5. At the workstation, the authors conducted visual inspection for three

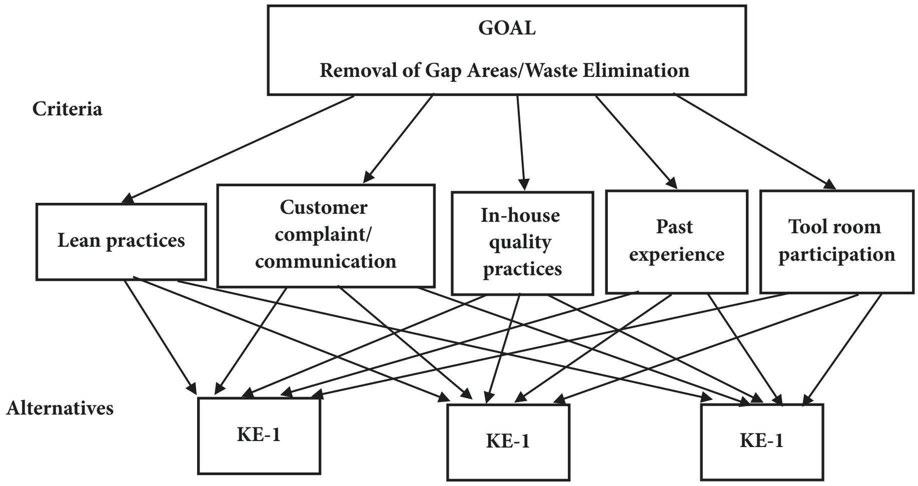

FIGURE 6: Structure for evaluation of Kaizen events.

TABLE 5: Calculations for average fuzzy rating, normalized fuzzy rating, and weighted normalized fuzzy rating.

Criteria	Kaizen events	M1	M2	M3	Aggregate fuzzy rating	Normalized fuzzy rating	Weighted normalized fuzzy rating
C1	KE1	G (5,7,9)	VG(7,9,9)	F(3,5,7)	(3,7,9)	(0.333,0.778,1.000)	(1.000,5.446,9.000)
	KE2	G (5,7,9)	F(3,5,7)	VG(7,7,9)	(3,6.33,9)	(0.333,0.703,1.000)	(1.000,4.449,9.000)
	KE3	F (3,5,7)	P(1,3,5)	G(5,7,9)	(1,5,9)	(0.111,0.556,1.000)	(0.111,2.780,9.000)
C2	KE1	G (5,7,9)	VG(7,9,9)	F(3,5,7)	(3,7,9)	(0.333,0.778,1.000)	(1.000,5.446,9.000)
	KE2	F(3,5,7)	VG(7,9,9)	VG(7,7,9)	(3,7,9)	(0.333,0.778,1.000)	(1.000,5.446,9.000)
	KE3	F(3,5,7)	F(3,5,7)	G(5,7,9)	(3,5.66,7)	(0.333,0.628,0.778)	(1.000,3.554,5.446)
C3	KE1	VG(7,9,9)	VP(1,1,3)	F(3,5,7)	(1,5,9)	(0.111,0.778,1.000)	(0.111,3.890,9.000)
	KE2	F(3,5,7)	F(3,5,7)	VG(7,7,9)	(3,5.66,9)	(0.333,0.628,1.000)	(1.000,3.554,9.000)
	KE3	F (3,5,7)	F(3,5,7)	F(3,5,7)	(3,4.33,9)	(0.333,0.481,1.000)	(1.000,2.082,9.000)
C4	KE1	P (1,3,5)	VG(7,9,9)	F(3,5,7)	(1,5.66,9)	(0.111,0.628,1.000)	(0.111,3.554,9.000)
	KE2	G (5,7,9)	VP (1,3,5)	G(3,5,7)	(1,5,9)	(0.111,0.556,1.000)	(0.111,2.780,9.000)
	KE3	F (3,5,7)	F (3,5,7)	G(5,7,9)	(3,5.66,9)	(0.333,0.628,1.000)	(1.000,3.554,9.000)
C5	KE1	G (5,7,9)	G (5,7,9)	F(3,5,7)	(3,6.33,9)	(0.333,0.703,1.000)	(1.000,4.449,9.000)
	KE2	VG (7,9,9)	G (5,7,9)	F(3,5,7)	(3,7,9)	(0.333,0.778,1.000)	(1.000,5.446,9.000)
	KE3	G (5,7,9)	P(1,3,5)	VG(7,7,9)	(1,5.66,9)	(0.111,0.628,1.000)	(0.111,3.554,9.000)

TABLE 6: Values of FNIS and FPIS.

Criterion	C1	C2	C3	C4	C5
FNIS	0.111	1.000	0.111	0.111	0.111
FPIS	9.000	9.000	9.000	9.000	9.000

TABLE 7: Comparing the closeness coefficient of KEs.

	d_{i+}	d_{i-}	CC_i	Ranking
KE-1	0.527023	0.268328	0.337371	**3**
KE-2	0.159926	0.496233	0.756269	**1**
KE-3	0.379473	0.376501	0.498034	**2**

hours. Three work pieces out of eighty-nine reported "chattering/tool marks" and "chamfer not good" after performing P5 process. In order to eradicate the existing problem, the snap type fixture was recommended to replace the screw mounted fixture for fastening of SKDM (Figure 7).

Implementation of Recommended Snap Type Fixture Design for Reducing Rejection Rate at P5. The problem was resolved by replacing screw type fixture to snap type fixture, in which the fastening activity was completed through the snap. In this fixture, two slots were designed, in which two workpieces were mounted on the same time for milling operation. This newly designed fixture eliminated quality problem along with ease in fastening activities. The production was monitored for two days and no "chattering/tool mark" was reported in the production of 1020

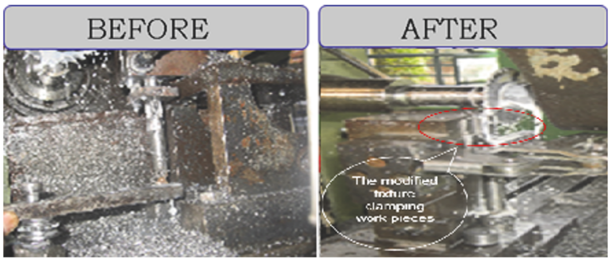

Figure 7: Fastening fixture before and after VSM implementation.

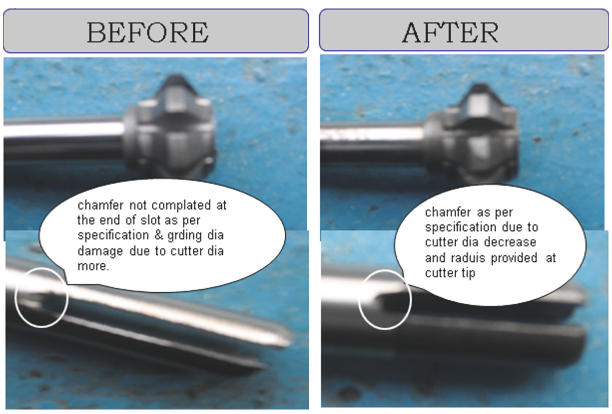

Figure 8: The workpiece before and after VSM implementation.

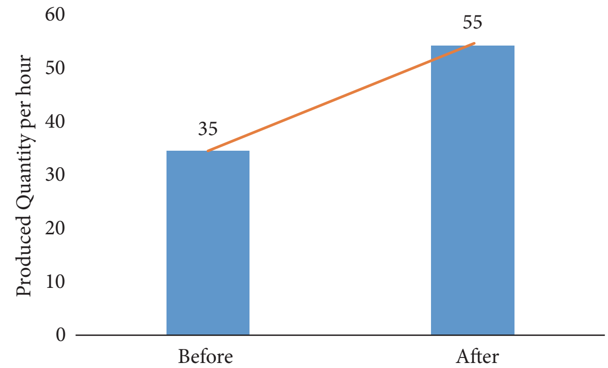

Figure 9: Before and after production quantity per hour.

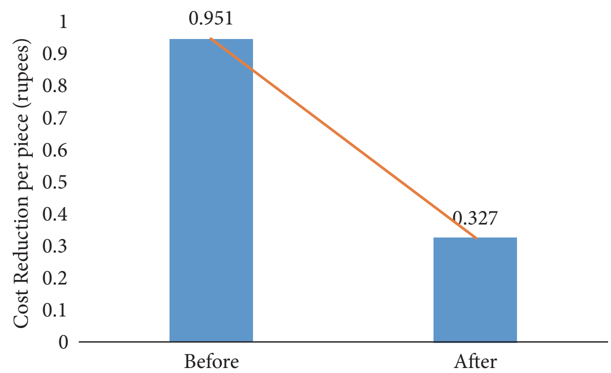

Figure 10: Before and after cost per piece.

pieces (Figure 8). This KE was applied within twenty-two days.

After VSM implementation, the result is analyzed, in which lean benefits are observed as reduction in fastening time at P5 by 58.73% (from 63 seconds to 26 seconds), PL time by 69.49% (from 18.031 to 5.5 days), per work piece cost by 60.71% (Figure 10), and total CT by 69.64% (from 336 seconds to 101 seconds) and increase in production per hour by 57.15% at P5 (Figure 9). The new process removed rejection cost of 3.1k USD per year.

8. Conclusion

In order to achieve significant lean benefits, it is important to understand the whole system of any organization. In this study, an effort has been made to apply Lean-Kaizen concept with VSM tool in SKDM line of ABC. The fuzzy-TOPSIS was applied to select the most appropriate KE that optimizes the lean benefits as cost reduction, lead time reduction, inventory level reduction, CT reduction, production improvement, and quality improvement of the product. The Lean-Kaizen with VSM-fuzzy technique is found to be an effective technique that assists in eliminating waste in the organization and motivating individuals to achieve goals of the organization. This study can help managers and practitioners to handle waste removal challenges in real-time working situations at the shop floor. The study highlights the following points:

(i) The endeavor has been made for Lean-Kaizen implementation with VSM-fuzzy technique in order to optimize the benefit of KEs.

(ii) Besides many researches based on the hypothetical concept of Lean-Kaizen and fuzzy-TOPSIS, the efforts have been made to explore the practical validation of combination of the three techniques, Lean, Kaizen, and Fuzzy-TOPSIS, in the context of Indian SSE.

(iii) The study provides a road map for implementing Lean-Kaizen concept in Indian production industry for continuous improvement.

This study provides a wider view of different practical approach of lean manufacturing and thus can help researchers and practitioners to compare their KE performance. A well-established cost-based theoretical framework can also be developed for a wide range of manufacturing industries for getting benefits in product, process, and services.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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