Performance measurement system for a lean manufacturing setting

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Abstract

Purpose – *The purpose of this paper is to propose a performance measurement system for a lean manufacturing environment, which assesses the multi-dimensional performance of lean manufacturing.*

Design/methodology/approach – *Following a case study approach, structured interviews were conducted to identify the parameters to measure the performance of a lean manufacturing apparel company. A model was developed with the analytical hierarchical process to assess the performance.*

Findings – *The proposed model consists of three levels: first level (overall manufacturing performance), second level (criteria that represent the stakeholders' view of manufacturing performance) and third level (sub-criteria for the criteria which represent the areas affected by lean manufacturing). The model connects indicators that measure manufacturing performance with the areas required improvements, according to their relative importance to stakeholders.*

Research limitations/implications – *The interviewers' perspectives were used to determine the importance of each manufacturing area for stakeholders. Key performance measures can vary from company to company.*

Practical implications – *Managers can use this model to identify important areas for manufacturing performance and the performance improvements driven by different types of lean practices. The results revealed that identifying stakeholders' requirements was an important aspect of evaluating manufacturing performance.*

Social implications – *The model embeds a stakeholder approach in performance measurement, thereby providing a comprehensive model to assess performance.*

Originality/value – *This study applies the stakeholder view to identify the multi-dimensional nature of performance in a lean manufacturing setting. It also defines the key performance measures using lean practices.*

Keywords *Analytical hierarchy process, Lean management, Lean, Performance measurement, Analytical hierarchal model*

Paper type *Case study*

Introduction

Lean manufacturing is increasingly gaining popularity as a way to improve organizational performance and competitiveness by uplifting performance in terms of reduced lead times, small batch sizes, quick responses and financial performance (Chavez *et al.*, 2015; Hofer *et al.*, 2012; Ketokivi and Schroeder, 2004; Shah and Ward, 2007). Lean implementation involves activities such as employee development, training and empowerment which result in improved organizational performance (Alagaraja, 2014; Fullerton and Wempe, 2009; Kristensen and Israelsen, 2014; Worley and Doolen , 2015). However, there is a lack of performance measurement systems (PMSs) that can evaluate the overall performance improvements associated with lean manufacturing. This study voids this gap by proposing a PMS that assesses multi-dimensional organizational improvement result in lean manufacturing.

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PMSs have been evolved over the period starting from the concept of activity-based costing (ABC) during the 1970s and 1980s, which analyzes the indirect costs within a company and identifies activities that cause those costs (Mohammadzadeh *et al.*, 2011; Neely *et al.*, 1995; Tangen, 2004). Since then many PMSs were developed such as the theory of constraints (Goldratt, 1990), Sink and Tuttle model (Sink and Tuttle, 1990), performance pyramid (Lynch and Cross, 1991), balanced scorecard (Kaplan and Norton, 1992) and performance prism (Neely *et al.*, 2001). The Sink and Tuttle model assumes organizational performance as a complex inter-relationship between seven performance criteria, including effectiveness, efficiency, quality, productivity, quality of work life, innovation and profitability (Sink and Tuttle, 1990). The performance pyramid considers the hierarchical breakdown of the organizational objectives into operational performance measures (Tangen, 2004; Wedman, 2010). In contrast to other methods, the performance prism adopted multiple perspectives to assess performance. These perspectives are stakeholder satisfaction, strategies, processes, capabilities and stakeholder contribution (Neely *et al.*, 2001). However, the performance prism offers little about how performance measures are being realized in PMSs used by companies.

The most noteworthy change in PMSs occurred with Kaplan and Norton's balanced scorecard that develops measures with respect to four stakeholder aspects, namely, financial, customer, business process and innovation perspectives (Kaplan and Norton, 1992; Neely, 2005). The development of business models and frameworks such as Malcolm Baldrige National Quality Award and other quality models also provide multiple insights into PMSs (Yadav and Sagar, 2013). With the development of manufacturing tools and techniques such as lean and world-class manufacturing, PMSs were further needed to capture performance results in these management practices (Nudurupati *et al.*, 2011; Taticchi *et al.*, 2012). However, none of these PMSs capture overall organizational performance results in lean manufacturing.

Among the PMSs for lean manufacturing environment are the models developed by Karlsson and Åhlström (1996), Sanchez and Perez (2001), Khadem *et al.* (2008) and Gama and Cavenaghi (2009). The model developed by Karlsson and Åhlström (1996) can assess operational changes in lean manufacturing. Sanchez and Perez (2001) developed 36 indicators that assess manufacturing changes in lean manufacturing. These indicators were classified into groups: zero value activities, continuous improvement, teamwork, Just-In-Time (JIT) production and delivery, suppliers' integration and flexible information system. Khadem *et al.* (2008) proposed primary and secondary metrics to evaluate the performance in terms of the production rate, quality, machine utilization, tardiness, lead time and inventory levels. Primary metrics are called lean metrics and include dock-to-dock time, first-time-through capability, overall equipment efficiency and build-to-schedule ratio. The secondary metrics include on-hand inventory, value-adding ratio, manufacturing cycle time, 5S diagnostic rating and square footage required. A common feature of all these PMSs is that they only capture operational performance.

Some other scholars attempted to link performance measures used in the lean environment to the organizational strategies and the supply chain. Among them, Gama and Cavenaghi (2009) presented a PMS using A3 reports – a tool for process improvement. This PMS presents organizational strategies and performance areas that need more attention. Singh *et al.* (2010) developed an index to assess performance in terms of supplier issues, investment priorities, lean practices, wastes and customer issues. However, these models lack the stakeholder perspective to determine the important performance areas. A vital aspect of lean manufacturing is meeting stakeholders' demand, particularly meeting stakeholders' expectation through manufacturing operation (Bhasin, 2008). Manufacturing plants that link corporate goals to performance measurement perform well (Sim and Koh, 2001). Consequently, developing a PMS that can capture performance results in lean manufacturing with their significance to stakeholders is a central problem.

Developing a PMS is a multi-criteria decision-making problem as the performance is multi-dimensional (Neely, 1999; Ketokivi and Schroeder, 2004). Among different methods that have been evolved to solve multi-criteria decision-making problems, the analytical hierarchical process (AHP) is a widely accepted technique discussed in the performance management literature (Ajami and Ketabi, 2012; Badurdeen *et al.*, 2011; Shahin and Mahbod, 2007). Therefore, this study used the AHP approach to develop a PMS for lean manufacturing setting that captured multi-dimensional manufacturing performance improvements.

The study entails interviewing experts and reviewing the literature to identify suitable evaluation criteria and sub-criteria for manufacturing performance. Then it applies AHP to determine the relative weights of the criteria and sub-criteria and thereby reveals the relative importance of each criterion on overall manufacturing performance. Additionally, a lean manufacturing Sri Lankan apparel company is used herein as an example of how performance can be measured using the proposed model. The study, therefore, develops a robust and comprehensive PMS model that assesses the impact of multi-dimensional changes on manufacturing performance result in lean practices.

Methodology

The objective of this research is to develop a model that is suitable for a PMS for a lean manufacturing environment that captures the operational performance and makes congruence between the organizational goals, stakeholder requirements and the lean concept in the Sri Lankan apparel sector. This research used a multi-method approach to collect, analyze and validate data to achieve the aforementioned objective.

AHP is an approach to a large, dynamic and complex real-world multi-criteria decision-making problems (Saaty and Vargas, 2012). It is used to solve complex decision-making problems in diverse areas, such as maintenance, location selection, performance measurement, resource allocation and the selection of the best policy through a set of alternatives by setting priorities (Vaidya and Kumar, 2006). AHP has been successfully applied to solve performance measurement issues. For example, Shahin and Mahbod (2007) used AHP to prioritize organizational key performance indicators (KPIs) in relation to organizational goals. Ajami and Ketabi (2012) applied AHP to evaluate the performance of the Medical Records Departments in Iran. Badurdeen *et al.* (2011) used AHP to measure the organizational transformation in implementing lean. Therefore, this study used the AHP method with the steps of calculation as follows (adopted from Wabalickis, 1988):

- Define the problem and the objective.
- Structure the hierarchy from the top through the intermediate levels to the lowest level. The objective of the problem is identified at level 1 (top). The decision of meeting the objective is made based on several criteria given at level 2. Sub-criteria at the lower levels are identified for the major criteria at the upper level. The alternatives to be evaluated are identified at the lowest level of the hierarchy.
- Construct a set of pairwise comparison matrices for each of the lower levels. An element at the higher level is called a governing element for those at the lower levels. A governing element contributes to or affects the elements at the lower level. The lower level elements are compared with each other with respect to their effect on the governing element. This provides a pairwise comparison matrix that is constructed as follows:

  Let $C_1, C_2, \ldots, C_n$ be the set of elements, and let a_{ij} denote a quantified judgment on a pair of elements C_i and C_j. The pairwise comparisons are performed based on the relative importance of the elements. These judgments are measured in integer values 1 to 9, where 1 = "equally important," 3 = "slightly more important," 5 = "strongly more important," 7 = "demonstrably more important," 9 = "absolutely more important" and 2, 4, 6 and 8 denote the intermediate values when compromise is needed. If an element C_i is more important than an element C_j, then the integer a_{ij} is entered in row C_i, column C_j, and the reciprocal ($1/a_{ij}$) is entered in row C_j, column C_i. If the elements being compared have equal importance, one is assigned to both positions. This yields an $n \times n$ matrix as follows:

	C_1	C_2		C_n
C_1	1	a_{12}	...	a_{1n}
C_2	$1/a_{12}$	1	...	a_{2n}
	...	...	...	...
	...	...	...	...
C_n	$1/a_{1n}$	$1/a_{2n}$	...	1

where $a_{ii} = 1$ and $a_{ji} = 1/a_{ij}$, and i and $j = 1, 2, 3, \ldots, n$.

- The consistency of the judgments is determined using the maximum eigenvalue of the pairwise comparison matrix.

  Eigenvalues of the pairwise matrix are given by Det $(A - \lambda I) = 0$

  where

  A = the pairwise comparison matrix

  λ = eigenvalues

  I = the unit matrix.

  Let λ_{max} be the maximum eigenvalue of the pairwise comparison matrix, then

  Consistency index (CI) = $(\lambda_{max} - n)/(n - 1)$

  Consistency ratio (CR) = CI/RCI for n

  where

  RCI = the random consistency index

  n = the number of elements.

  CR of less than or equal to 0.1 represents consistent judgment.
- To determine the weight for each criterion, first normalize the column of numbers by dividing each entry by the sum of all entries. Then, take the average of normalized values of each row as the weight for a respective criterion of the row.
- Perform steps 3-5 for each set of sub-criteria.
- Similarly, perform the alternative analysis for the lowest level of sub-criteria.
- Calculate the priority score for each alternative in the following way:

  Let p be the main criteria, q the sub-criteria and r the alternative.

Then, the priority score for the alternative r is given by:

$$S_r = \sum_{p=1}^{L} \sum_{q=1}^{m_p} W_p W_{p_q} W_{q_r}$$

where:

w_p = weight of the main criteria;

w_{p_q} = weight of sub-criteria q with respect to the main criteria p;

w_{q_r} = weight of alternative r with respect to sub-criteria q;

L = number of the main criteria; and

m_p = number of sub-criteria for the pth criterion.

The best alternative can be selected based on the priority scores.

Model

Applying AHP for developing a PMS for lean manufacturing apparel companies in Sri Lanka

The AHP model for developing a PMS involves the following steps:

- Define the problem and determine the objective.
- Establish a hierarchical structure by breaking down the performance measurement problem into a hierarchy of inter-related decision elements, including the goal, criteria and sub-criteria. This is shown in Figure 1.

  The highest level (goal) is the overall objective. The secondary level (criteria) defines the alternatives/options to reach the overall objective. The tertiary level (sub-criteria) encompasses the value drivers and their associated metrics relating to the secondary level alternatives/options (i.e. frontline activities that contribute positively to the overall objective of increasing value) which are the decision elements.
- Establish a pairwise comparison matrix comparing the decision elements and giving them relative scores. This is achieved by judging the relative weight or importance of each of the value drivers to the firm's ability to succeed in achieving its overall objective.
- Calculate the eigenvalue and eigenvector of each pairwise comparison matrix followed by the test for consistency of each comparison matrix.
- Calculate the relative weight for each criterion.

Application

This study takes an example of a lean manufacturing company in the apparel sector in Sri Lanka. The proposed PMS was tested in this company. The model was developed based on the findings of the structured interviews supported through the literature.

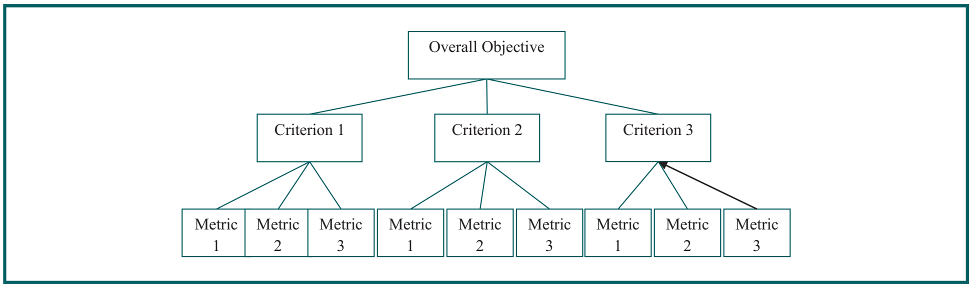
Step 1: Define the problem and objective

The problem is the lack of a PMS model to measure manufacturing performance in a lean environment. Therefore, the objective is to develop such a model by identifying criteria and their relative importance in measuring manufacturing performance in a lean environment.

Step 2: Establish the hierarchical structure

The objective of the hierarchy is to measure the overall manufacturing performance, which satisfies stakeholders' expectations. The structured interviews were conducted with six managers from four apparel companies that practice lean. The interview questions enquired the expectations of the stakeholders (such as shareholders, suppliers, customers,

Figure 1 AHP process



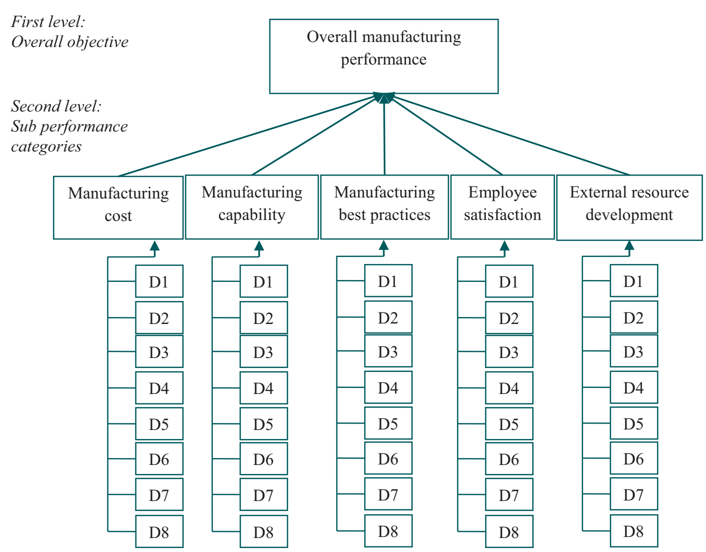
employees and community) about the company's manufacturing performance. Then the similar requirements were clustered. These clusters represent the criteria for manufacturing performance in a lean setting. These were manufacturing costs, manufacturing capability, manufacturing best practices, employee satisfaction and external resource development. Because the clusters represent the stakeholders' view of manufacturing performance, that level was termed as the "stakeholder value" level.

Sub-criteria of the criteria were determined from the literature using indicators developed by Sanchez and Perez (2001), which identify the changing areas of an organization from lean manufacturing. These changing areas are the key performing areas (KPAs) that represent performance improvement through lean. These sub-criteria include the elimination of zero-value activities, continuous improvement, teamwork, JIT production and delivery, suppliers' integration and flexible information system. Additionally, safety and morale were introduced to the above set as supported by the literature (Worley and Doolen, 2015) and interviews. Finally, the hierarchical structure was established with the above objective, criteria and sub-criteria and is shown in Figure 2.

Step 3: Establish a pairwise comparison matrix

A survey was conducted in the case company with the executive and above-executive level people involved in the production. A questionnaire was used to collect data. Ten people participated in the study. However, only six questionnaires were returned, which resulted in a response rate of 60 per cent. The sample is deemed appropriate as the validity of the survey results based on the consistency ratio and not on the sample size (Saaty and Vargas, 2012). The relative scores provided were aggregated using the geometric mean method. The aggregate pairwise comparison matrix of the criteria is listed in Table I and that for the sub-criteria is listed in Table II. The cell values in the lower diagonal of Tables I

Figure 2 Performance hierarchy in a lean manufacturing environment



Notes: D1 = elimination of zero-value activities; D2 = continuous improvement; D3 = teamwork; D4 = JIT production and delivery; D5 = suppliers' integration; D6 = flexible information system; D7 = safety; D8 = morale

Table I Pairwise comparison of stakeholder values on manufacturing performance

Manufacturing performance criteria	*Manufacturing cost*	*Manufacturing capability*	*Best practices*	*Employee satisfaction*	*External resource development*
Manufacturing cost	–	1.2	1.3	1.2	5
Manufacturing capability		–	2	1.6	4.7
Best practices			–	1.4	3.4
Employee satisfaction				–	3.4
External resource development					–

and II are the reciprocals of the respective values in the upper diagonal of the table. These values are therefore not shown in the tables.

Step 4: Consistency test

The above pairwise matrices were fed into Expert Choice software for the analysis. The consistency ratios were determined, and it was revealed that for the criteria and sub-criteria, they were <0.1, indicating the consistency of judgments.

Step 5: Estimate the relative weights of elements of each level

Relative weights for each level were estimated from the aggregated values of the interviewers. Table III lists the results of weights of criteria for overall manufacturing performance that represent stakeholder expectations in terms of manufacturing requirements.

According to that, for overall manufacturing performance, the relative weights obtained for each criterion are ordered as manufacturing capability (0.291), manufacturing cost (0.273), manufacturing best practices (0.198), employee satisfaction (0.183) and the external resource development (0.056).

The weights obtained for KPAs on stakeholder expectations are given in Table IV. According to the table, 15.5 per cent of manufacturing cost improvement is determined by the elimination of zero-value activities. The contributions of other KPAs to manufacturing cost are 14.8 per cent of continuous improvement, 14 per cent of teamwork, 15.9 per cent of JIT production and delivery, 11.4 per cent of supplier integration, 6.5 per cent of the flexible information system, 12.4 per cent of safety and 9.5 per cent of employee morale.

The elimination of zero-value activities accounts for 19.1 per cent of manufacturing capability, whereas 18.4 per cent of manufacturing capability is dependent on continuous improvement, 13.4 per cent on teamwork, 14.7 per cent on JIT production and delivery, 9.9 per cent on supplier integration, 8 per cent on flexible information system, 8.2 per cent on safety and 8.3 per cent on employee morale.

The elimination of zero-value activities determines 15.9 per cent of performance on manufacturing best practices. The contributions of other KPAs to manufacturing best practices include 14.6 per cent of continuous improvement, 12.5 per cent of teamwork, 13.8 per cent of JIT production and delivery, 10 per cent of supplier integration, 11.5 per cent of the flexible information system, 10.9 per cent of safety and 10.9 per cent of employee morale.

The elimination of zero-value activities accounts for 13.2 per cent of employee satisfaction, whereas the contributions of other KPAs to employee satisfaction include 12.1 per cent of continuous improvement, 12.8 per cent of teamwork, 13.9 per cent of JIT production and delivery, 10.2 per cent of supplier integration, 10.7 per cent of flexible information system, 12.6 per cent of safety and 14.4 per cent of employee morale.

The elimination of zero-value activities determines 12.4 per cent of external resource development, whereas the contributions of other KPAs to external resource

Table II Pairwise comparison of lean KPAs on stakeholder values

Comparison pair	Manufacturing cost	Manufacturing capability	Best practices	Employee satisfaction	External resource development
Elimination of zero-value activities VS					
Continuous improvement	1	1.6	1.2	1.1	0.8
Multi-functional teams	1.4	1.6	1.6	1.1	2.9
JIT production and delivery	1	1.6	1.2	1.1	1.6
Supplier integration	1.4	1.6	1.6	1.3	0.6
Flexible information system	2.9	2.1	1.6	0.8	1.2
Safety	1	2.3	1.2	1	0.7
Morale	1.4	1.6	1.2	1	0.7
Continuous improvement VS					
Multi-functional teams	1	2.1	1.2	0.8	4.5
JIT production and delivery	1	1.6	1.2	0.8	1.9
Supplier integration	1.2	2.2	1.6	1.3	0.4
Flexible information system	2.5	2.1	1.6	1.2	1.2
Safety	1.4	2.3	1.2	1	0.7
Morale	1.4	1.6	1.2	1	0.7
Multi-functional teams VS					
JIT production and delivery	0.8	1.1	0.9	0.8	1
Supplier integration	1.2	1.9	1.4	1.2	0.5
Flexible information system	2.7	1.9	1.6	1.2	0.9
Safety	1.4	1.7	0.9	1	0.6
Morale	1.4	1.6	1.2	1	0.6
JIT production and delivery VS					
Supplier integration	1.4	2.2	1.6	1.3	0.6
Flexible information system	2.9	2.2	1.6	1.3	1.2
Safety	1.4	2.3	1.2	1	0.7
Morale	1.4	1.6	1.2	1	0.7
Supplier integration VS					
Flexible information system	2.5	1.9	1.4	1.2	1.2
Safety	0.7	1.6	0.9	0.7	0.8
Morale	1.1	1.2	0.9	0.7	0.8
Flexible information system VS					
Safety	1	1.6	2.7	1	1
Morale	0.8	1	1	0.5	1.6
Safety VS					
Morale	2	2.2	1.2	0.8	1

Table III Relative ranking of stakeholder values determined in terms of manufacturing requirements on overall performance

Stakeholder value	Weightage
Manufacturing cost	0.273
Manufacturing capability	0.291
Manufacturing best practices	0.198
Employee satisfaction	0.183
External resource development	0.056
Consistency ratio	0.01

development include 14.5 per cent of continuous improvement, 7 per cent of teamwork, 9.2 per cent of JIT production and delivery, 16.4 per cent of supplier integration, 11.5 per cent of flexible information system, 14.8 per cent of safety and 14.2 per cent of employee morale.

Table IV Relative ranking of lean KPAs on stakeholder values

Lean KPAs	*Weightage on stakeholder values*				
	Manufacturing cost	*Manufacturing capability*	*Manufacturing best practices*	*Employee satisfaction*	*External resource development*
Elimination of zero-value activities	0.155	0.191	0.159	0.132	0.124
Continuous improvement	0.148	0.184	0.146	0.121	0.145
Teamwork	0.140	0.134	0.125	0.128	0.070
JIT production and delivery	0.159	0.147	0.138	0.139	0.092
Supplier integration	0.114	0.099	0.100	0.102	0.164
Flexible information system	0.065	0.080	0.115	0.107	0.115
Safety	0.124	0.082	0.109	0.126	0.148
Morale	0.095	0.083	0.109	0.144	0.142
Consistency ratio	0.02	0.03	0.02	0.01	0.04

Furthermore, the weights of lean KPAs on overall manufacturing performance are shown in Table V. According to the table, the elimination of zero-value activities has 16 per cent of importance to the overall manufacturing performance, whereas the importance of continuous improvement is 15.3 per cent, JIT production and delivery is 14.4 per cent, teamwork is 12.9 per cent, safety is 11.1 per cent, supplier integration is 10.8 per cent, employee morale is 10.6 per cent and flexible information system is 9 per cent.

Conclusion

The design of a PMS should consider the multi-dimensional nature of performance and the areas significant for the performance. The performance measures should also be linked with the organizational objectives and stakeholder expectations. Yet, current PMSs in lean manufacturing environments are lacking in integrating all these aspects, particularly in identifying stakeholders' expectations in designing measures and quantifying the relative importance of each performance measure on overall manufacturing performance. This study proposes a PMS model in a lean manufacturing environment, addressing the aforementioned drawbacks and tested in a Sri Lankan company. It develops a robust and comprehensive PMS model that assesses the performance result in lean manufacturing that is important in meeting stakeholders' requirements of manufacturing performance.

The top level of the model is the overall manufacturing performance, which reflects the strategic-level expectations, thereby representing the company's strategic objectives. The second level captures the stakeholders' expectations of the company's manufacturing performance, which is represented by manufacturing requirements. The bottom level identifies the manufacturing areas affected by lean, which are denoted as KPAs. It was assumed that categories belong to stakeholder values and manufacturing areas were not

Table V Global ranking of lean KPAs on overall manufacturing performance

Lean KPAs	*Weightage*
Elimination of zero-value activities	0.160
Continuous improvement	0.153
JIT production and delivery	0.144
Teamwork	0.129
Safety	0.111
Supplier integration	0.108
Morale	0.106
Flexible information system	0.090
Consistency ratio	0.02

dependent. The model, therefore, investigates how lean KPAs and the manufacturing requirements defined by stakeholders drive the overall manufacturing performance. In addition, it defines the degree of importance of the lower level variables on the overall manufacturing performance.

The model identifies the manufacturing areas improved by lean practices – areas that are important for stakeholders. The model is independent of the lean practices currently implemented at the company. It reveals the avenues for managers suggesting the key areas to be addressed through lean practices. The overall manufacturing performance can be improved by implementing appropriate lean tools in the identified areas. This model, therefore, meets the criteria suggested by Huber (2015) where a proper PMS supports the robustness and the sustainability of the company by identifying areas to improve. Furthermore, the study reveals the types of KPIs that should be set by an organization to monitor performance. By identifying the essential areas in which KPIs to be set, organizations can effectively control their performance toward competitiveness.

The case study reveals that the manufacturing capability is the most important criterion for manufacturing performance of the company, and the manufacturing cost is the next most important factor. However, the difference of the relative importance is very small. Therefore, these two aspects should be clearly measured by the PMS. The elimination of zero-value activities and continuous improvement are the most important aspects of manufacturing capability, whereas the JIT production and delivery are the most important consideration for manufacturing cost. The importance values obtained for the elimination of zero-value activities, continuous improvement and teamwork lie close together. Therefore, the elimination of zero-value activities and continuous improvement are highly critical for manufacturing performance. The results are similar to those drawn by Chauhan and Singh (2012) who noted that the elimination of waste, continuous improvement and just-in-time principles are the most important KPAs to realize lean manufacturing. The company, therefore, should focus on adopting appropriate lean tools to improve those areas.

The company can introduce a PMS by comparing the present performance measures with the measures identified in the literature for the KPAs proposed by the model. The other apparel companies that practice lean manufacturing can also use this model as a guiding framework to decide on the areas to be improved through lean manufacturing. Furthermore, the performance measures introduced in this study can be used to determine the relevant KPIs.

Managers can use the relative ranking of stakeholder values on overall manufacturing performance to determine the most important manufacturing aspects that the company should focus on. The relative rankings of lean KPAs on stakeholder values help managers to identify the most and least influential changes driven by lean practices on each manufacturing requirement. This ranking further assists them to take necessary actions to adjust lean tools/techniques to enhance the performance of the respective manufacturing requirement. Moreover, the global ranking of KPAs provides an understanding of the importance of each KPA for the overall manufacturing performance of the company. Therefore, the proposed model assists to identify lean practices more relevant to the organization. Managers can use this as a guide in a continuous improvement exercise to enhance the overall performance of their organizations.

Limitations and further research

The stakeholder values for the proposed model were identified from the interviews conducted with the managers of the company. This may not reveal the stakeholders' expectations completely and accurately. The best way to identify stakeholders' requirements is to collect information from the stakeholders themselves. By interviewing all or a sample of stakeholders from each category (e.g. suppliers, customers and employees), the more precise stakeholder values would have been identified.

Moreover, the performance measures introduced in this study to measure lean KPAs were drawn from the literature. However, the suitability of these performance measures should be verified with the characteristics of the apparel industry.

Another limitation is that this study was based on the assumption that the categories belong to stakeholder values and the manufacturing areas were not dependent. However, the dependencies may exist among these categories.

This research opens avenues for future studies in the following ways. The model reveals the important areas in organizational performance associated with lean manufacturing. This can be further extended by introducing another level below to the lean KPAs to represent performance measures for each lean KPA. This approach will directly provide answers to the KPIs to be adopted by the company. Another approach is to incorporate various lean tools and practices below the lean KPA level, which will determine the appropriate lean tools/practices in meeting stakeholder requirements of manufacturing performance.

The study assumed that the categories belong to stakeholder values, and manufacturing areas were not dependent. Therefore, improvements are further possible with the use of the analytical network process approach as it is suitable when the functional dependency is present.

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