J. Appl. Environ. Biol. Sci., 5(10S)606-611, 2015

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Lean assessment in Imam Khomeini Hospital of Kermanshah through fuzzy logic

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Received: April 20, 2015
Accepted: June 15, 2015

ABSTRACT

The health care has increasingly become complex and widespread. The reduced resources, increased expectations of society and the challenges facing these organizations have led the health care service around the world to admission of process improvement methods in manufacturing sector like the lean degree. This lean production along with the performance assessment is the way for achieving the objectives of these organizations. In this regard, this paper evaluates the performance in Imam Khomeini Hospital of Kermanshah through fuzzy logic and identifies its weaknesses in accordance with the lean approach. The results of calculations show moderate status for hospital.
KEYWORDS: Lean, Performance assessment, Healthcare, Fuzzy Logic.

INTRODUCTION

Due to the challenges facing the hospitals, most of them are applying the lean concepts to improve the profitability, medical care, operation and other aspects of their operations which may force them to change the processes. The physical components are the important elements of treatment process success and the demand for these components is largely unchanged. These components and materials are provided by the support sector of healthcare supply chain, and the lean methods in this sector can lead to the economical processes and avoid wasting. Chase argues that the support sector of service operation is largely similar to the factories, thus the lean methods in this sector can be largely accepted similar to the production sectors, and thus the cost reduction methods can also be utilized (Chase, 1996); and the utilization of materials and equipment in treatment process should follow the lean approach. According to the flow of materials, the main concern is how to supply and manage the products and use these products in a cost effective method. According to the literature, the lean degree was first introduced in healthcare and service of Great Britain in 2001 and then in the United States in 2002, although the work literature shows the considerable variation in applying the lean degree with different approaches and ranges (Radnor and Holweg,2010). The development of management practices in clinical service organizations is one of the most prominent and controversial types of development (Alford,1975). According to the reports of lean approach application in treatment especially in hospitals, it has the positive impact on the customer and employee satisfaction quality, cost and time (Papadopoulos et al, 2011). Toussaint and Berry have declared that the lean approach is an innovative management approach which has been successful in healthcare organizations and promises to improve the quality and efficiency while controlling the costs in providing the optimal healthcares for patient (Toussaint and Berry, 2013); the lean application is among the practical instances by Dixon et al. The investigation of emergency in 4 hospitals, where applied the lean strategy and the observation of their behavioral changes over time indicate that the length of staying was reduced in three cases of emergency, despite the increased volume of illness in all 4 emergency departments. According to the largest results of these emergency departments, the front line employees have actively participated in changes of lean-based processes of company and the leaders' continued commitment to the lean approach has been the factor which significantly affects the results in the second and third years of lean application (Dickson et al,2009). In another study, Radnor et al conducted four multilevel four case studies on the lean application in UK public service (Radnor et al, 2012).

Since these conducted studies have not provided the required criteria for performance evaluation of hospitals, this study introduces the lean criteria in hospital and evaluates the performance of Imam Khomeini Hospital of Kermanshah in implementing these criteria through investigating the conducted studies in the field of industry lean production. Finally, the strengths and weaknesses of organization are identified in this regard. Therefore, the managers can encourage the employees to help the organization by themselves as well as introducing their weaknesses.

The proposed approach for performance evaluation and the criteria of lean approach in hospitals are presented as follows, and then we provide the performance evaluation, conclusion and future suggestions.

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METHODOLOGY

Since the fuzzy logic proposes the appropriate tool for dealing with certain inexact methods by considering the ambiguity and uncertainty, it has been widely used in the field of management. In this regard, a model based on fuzzy approach with the following steps is offered for evaluating the performance of supply chain according to the lean approache in studied hospital:

Step 1: Justifying the employees participating in the evaluation by distributing the leaflets containing the information about the lean supply chain and relevant concepts in hospital

Step 2: Determining the linguistic variables and terms: In this research, the fuzzy numbers of linguistic variables for ranking the status and determining the importance are according to the Table (1). The main advantage of linguistic variables is their easier utilization than the other methods of scoring.

Table 1 Fuzzy numbers used for approximation of linguistic variables (Lin et al. 2006)

		Fuzzy number
Performance – rating	Worst (W)	(0, 0.5, 1.5)
	Very poor (VP)	(1, 2, 3)
	Poor (P)	(2, 3.5, 5)
	Fair (F)	(3, 5, 7)
	Good (G)	(5, 6.5, 8)
	Very good (VG)	(7, 8, 9)
	Excellent (E)	(8.5, 9.5, 10)
Importance – weighting	Very low (VL)	(0, 0.05, 0.15)
	Low (L)	(0.1, 0.2, 0.3)
	Fairly low (FL)	(0.2, 0.35, 0.5)
	Medium (M)	(0.3, 0.5, 0.7)
	Fairly high (FH)	(0.5, 0.65, 0.8)
	High (H)	(0.7, 0.8, 0.9)
	Very high (VH)	(0.85, 0.85, 0.1)

Step 3: Evaluators' consensus and feedback: Numerous models are utilized for receiving the participants' feedback in evaluations and since the use of mean operator is more other methods, this study also applies the arithmetic mean for collecting the experts' views and thus W_{ijk} and R_{ijk} are measured.

Step 4: The calculation of criteria is done through equation (1) (Lin et al. 2006).

$$GL_{ij} = \frac{\sum_{k=1}^{n}\left(W_{ijk} \times R_{ijk}\right)}{\sum_{k=1}^{n} W_{ijk}} \qquad (1)$$

Step 5: The rank is calculated using the equation (2).

$$R_i = \frac{\sum_{j=1}^{m}\left(GL_{ij} \times W_{ij}\right)}{\sum_{j=1}^{m} W_{ij}} \qquad (2)$$

Step 6: The fuzzy lean index (FLI) or the main index is calculated as follows:

$$FLI = \frac{\sum_{i=1}^{p}(W_i \times R_i)}{\sum_{i=1}^{p} W_i} \qquad (3)$$

Step 7: Calculating the lean level: The obtained index should be adapted to the relevant linguistic level after calculating the main index. Here, we utilize the Euclidean distance method which is one of the most common distance measures due to the simplicity, and according to Vinodh and Devadasan's view due to its accuracy and proximity to the human understanding of proximity (Vinodh and Devadasan, 2011). In fact, the Euclidean method measures the Euclidean distance of a fuzzy number from any other fuzzy number indicating the level of index in terms of linguistic variable. The Euclidean distance is measured according to the equation (4).

$$D(FLI, FS_i) = \sqrt{\sum_{x \in p}\left(f_{FGLI}(x) - f_{FS}(x)\right)^2} \qquad (4)$$

The Euclidean distance is calculated by each of the following lean levels in hospital:

$$FS = \{W_l, VP_l, P_l, F_l, G_l, VG_l, E_l\}$$

W_l indicates the worst lean status,VP_l: very poor,P_l: Poor, F_l: Fair, G_l : Good, VG_l : very good, and E_l: the Excellent lean status in hospital. Obviously, we provide the minimum Euclidean distance indicating the linguistic level or one of mentioned states.

Step 8: Fuzzy performance importance index(FPII): To improve the lean level in the hospital, the main problems can be identified in the organization through measuring the rank of fuzzy performance importance index (Lin et al. 2006). It should be noted that the factors with lower efficiency and higher importance are more effective for measuring this index and ranking the critical factors of failure, thus the importance of elements should be reversed and for consistency of these two factors and then multiplied by the rank of efficiency. This index is calculated using the equations (5) and (6).

$$W'_{ijk} = (1,1,1) - W_{ijk} \qquad (5)$$

$$FPII_{ijk} = W'_{ijk} \times R_{ijk} \qquad (6)$$

To obtain the score of ranking, the index should be first converted into the final numbers at this stage and after adapting each index to fuzzy values and finding the Euclidean distance and allocating the linguistic level. Here, the center of gravity method is utilized and the formula for converting the fuzzy numbers $FPII = (a, b, c)$ to final numbers is according to the equation (7).

$$Ranking\ Score = \frac{a + 4b + c}{6} \qquad (7)$$

Lean criteria in hospital

The lean thinking has five principles and the managers can fully applied the lean methods and techniques and maintain a sustainable principle by accurate understanding of these principles and the need for tying them together (Johansson and Abrahamsson, 2008). These principles are based on the basic hypothesis under which the organizations are composed of processes, and the organizations can successively create the value, reduce the losses and achieve the continuous improvement in a repeating process through involving these five principles (Radnor et al, 2012).

Here, the lean approach is presented based on five lean principles introduced by Vomack in healthcare and then the lean criteria are classified into following four groups (Womack et al, 1990):

1. The criteria which lead to the loss elimination;
2. The criteria which create value;
3. The criteria which pave the way for operation in order to achieve the value and move towards the value path;
4. The criteria which lead to the continuous improvement (pursuit of perfection, ensuring the lean approach).

waste elimination: To introduce the losses in the healthcare sector, five available losses in production environment are utilized as well as a criterion as the existing loss in human resources field because the service providers in health care organization have long direct connection with customer and thus the greatest value added is created by these people for customer and they can decide how to receive the customer demand (Rahimnia and Moghadasian, 2010). Therefore, an important volume of losses compared to production sectors can be created in this group (human resources).

Value increase: The lean approach seeks to create value for customer. Thus, the value should be initially determined according to the customer view and then created.

smooth the operation flow (infrastructures): According Langabeer*et al*, the infrastructures (investment in projects) have the in medium impact on achieving the goals in terms of value (Langabeer et al, 2009).

Continuous improvement (pursuit of perfection): The lean nature identifies the non-standardized work processes and then changes them to standardized processes which improve the performance following by improving the standardized process through planning- implementation- study (investigation) – action (Toussaint and Berry, 2013), so that each process has the best state of implementation.

The identified sub-criteria for each criterion are presented in Table(2).

Table 2 Lean criterion and sub-criteria in hospital

approach	criteria	sub-criteria
Lean(L_1)	waste elimination(L_{11})	Inventory(L_{111}) Motion(L_{112}) Waiting (Delay)(L_{113}) Over- Processing(L_{114}) Transportation(L_{115}) Overproduction(L_{116}) Defects(L_{117}) human resources(L_{118})
	Value increase(L_{12})	Capacity(L_{121}) Just in time (L_{122}) Quality(L_{123}) Customer satisfaction(L_{124}) employee satisfaction (L_{125}) Supplier Relationships(L_{126}) Total preventive maintenance(L_{127}) Supply and services Outsourcing(L_{128})
	smooth the operation flow(L_{13})	employee participation(L_{131}) Senior management support (L_{132}) Human Resources training(L_{133}) Using Information Technology(L_{134}) updating the equipment(L_{135})
	Continuous improvement (L_{14})	managers and staffperiodic meetings(L_{141}) re-engineering of treatment processes(L_{142}) performance-based payment system(L_{143}) Total Quality management(L_{144})

RESULTS AND DISSCUSSION

This research investigates the burn and emergency units of Imam Khomeini hospital in Kermanshah in terms of lean approach. A questionnaire is designed in this regard and distributed among a number of employees in these sectors. The definitions are provided for studied approaches of hospital in distributed questionnaires; and the questionnaire

distributor provides the information for evaluators in the case of ambiguity in criteria. The employees include the physicians, nurses and environmental experts with doctoral, master and bachelor degrees and five to twenty-five years of experience. The results of evaluating the evaluators' responses are presented in the following steps.

Step 1-3: The questionnaire is designed using the collected criteria and then distributed among evaluators, whose responses are collected according to the table (1) of fuzzy numbers and the mean views on the importance weight and performance of hospital for lean criteria are presented in Table (3).

Table 3 Mean ratings and collected weights of lean sub-criteria

criteria	sub-criteria	W_{ijk}	R_{ijk}
L_{11}	L_{111}	(0.35,0.48,0.55)	(2.4,3.95,5.5)
	L_{112}	(0.36,0.44,0.40)	(3,4.7,6.4)
	L_{113}	(0.5,0.59,0.43)	(3.4,4.85,6.35)
	L_{114}	(0.50,0.60,0.65)	(2.9,4.4,5.9)
	L_{115}	(0.41,0.56,0.66)	(3.2,4.85,6.5)
	L_{116}	(0.45,0.5,0.64)	(2.7,4.4,6.1)
	L_{117}	(0.56,0.64,0.54)	(5.1,5.3,7)
	L_{118}	(0.42,0.47,0.61)	(3.5,5.15,6.8)
L_{12}	L_{121}	(0.45,0.58,0.72)	(3.1,4.7,6.35)
	L_{122}	(0.6,0.71,0.69)	(3.1,4.85,6.65)
	L_{123}	(0.70,0.79,0.66)	(3.9,5.6,7.3)
	L_{124}	(0.58,0.71,0.68)	(4.2,5.9,7.6)
	L_{125}	(0.65,0.74,0.56)	(1.9,3.2,4.35)
	L_{126}	(0.38,0.51,0.65)	(3.2,5,6.8)
	L_{127}	(0.43,0.42,0.74)	(3,4.7,6.4)
	L_{128}	(0.45,0.61,0.77)	(2.1,3.65,5.2)
L_{13}	L_{131}	(0.59,0.71,0.76)	(3.7,5.3,6.9)
	L_{132}	(0.62,0.72,0.74)	(3.2,4.85,6.5)
	L_{133}	(0.67,0.76,0.62)	(3.5,5.15,6.8)
	L_{134}	(0.48,0.60,0.67)	(3,4.7,6.4)
	L_{135}	(0.67,0.76,0.62)	(2.6,3.8,5.15)
L_{14}	L_{141}	(0.54,0.66,0.7)	(3,4.55,6.15)
	L_{142}	(0.71,0.80,0.73)	(3.1,4.7,6.35)
	L_{143}	(0.64,0.71,0.56)	(2.1,3.35,4.75)
	L_{144}	(0.61,0.72,0.68)	(3.2,4.7,6.25)

Step 4:Using the equation (1), the criteria values are according to the Table (4).

Table 4 Aggregated weights and ratings of lean criteria

criteria	W_i	R_i
L_{11}	(0.44,0.54,0.56)	(3.36,4.72,6.31)
L_{12}	(0.53,0.63,0.68)	(3.09,4.72,6.35)
L_{13}	(0.60,0.71,0.68)	(3.20,4.76,6.38)
L_{14}	(0.62,0.72,0.67)	(2.85,4.33,5.94)

Step 5-6:The rank and importance weight of lean approach is calculated and the value of fuzzy lean index (main index) is as follows according to the equation (3).

FLI=(3.106, 4.620, 6.245)

Step 7:The Euclidean distance and distance of total index from various states of FS set are measured at this stage through equation (4). Using these values, we can indicate the status of hospital in terms of applying three approaches.

$D(FL,W_I)=7.010$، $D(FL,VP_I)=4.672$,$D(FL,P_I)=2.007$ ، $D(FL,F_I)=0.825$، $D(FL,VG_I)=5.846$، $D(FL,G_I)=3.194$, $D(FL,E_I)=8.186$

At this stage, the minimum Euclidean distance value indicates the hospital status and this value is for the state (0.825) of the moderate state.

Step 8:At this stage, the fuzzy performance importance index is measured through the equations (5) and (6), and then the center of gravity method (equation 7) is utilized for creating the ability to compare the numbers. The result of this index for lean criterion is presented in table (5).

Table 5Measuring the fuzzy performance importance index for lean sub-criteria

sub-criteria	$W`_{ijk}$	$FPII_{ijk}$	Ranking Score
L_{111}	(0.65,0.52,0.45)	(1.57,2.06,2.48)	2.046
L_{112}	(0.64,0.56,0.6)	(1.93,2.62,3.84)	2.71
L_{113}	(0.5,0.41,0.57)	(1.7,1.98,3.598)	2.203
L_{114}	(0.50,0.40,0.35)	(1.46,1.74,2.07)	1.749
L_{115}	(0.58,0.45,0.34)	(1.82,2.16,2.19)	2.115
L_{116}	(0.55,0.5,0.36)	(1.47,2.2,2.19)	2.077
L_{117}	(044,0.36,0.46)	(2.25,1.90,3.25)	2.184
L_{118}	(0.58,0.53,0.39)	(2.04,2.74,2.63)	2.603

L_{121}	(0.56,0.42,0.28)	(1.72,1.97,1.79)	1.895
L_{122}	(0.4,0.29,0.31)	(1.24,1.39,2.06)	1.475
L_{123}	(0.31,0.21,0.34)	(1.19,1.20,2.46)	1.405
L_{124}	(0.42,0.29,0.32)	(1.76,172,2.42)	1.84
L_{125}	(0.36,0.26,0.45)	(0.67,0.84,1.94)	0.998
L_{126}	(0.62,0.49,0.35)	(1.98,2.43,2.38)	2.348
L_{127}	(0.57,0.58,0.26)	(1.72,2.74,1.69)	2.391
L_{128}	(0.56,0.39,0.23)	(1.17,1.43,1.18)	1.342
L_{131}	(0.41,0.29,0.24)	(1.53,1.54,1.63)	1.56
L_{132}	(0.39,0.29,0.26)	(1.23,1.38,1.69)	1.409
L_{133}	(0.34,0.25,0.38)	(1.17,1.26,2.58)	1.467
L_{134}	(0.53,0.41,0.33)	(1.58,1.90,2.11)	1.884
L_{135}	(0.34,0.25,0.38)	(0.87,0.93,1.96)	1.092
L_{141}	(0.47,0.35,0.3)	(1.40,1.57,1.85)	1.587
L_{142}	(0.29,0.21,0.27)	(0.70,0.96,1.71)	1.078
L_{143}	(0.37,0.29,0.44)	(0.77,0.97,2.09)	1.124
L_{144}	(0.39,0.28,0.32)	(1.25,1.32,2)	1.419

According to the main index and the Euclidean distance of various states in hospital, the minimum distance is equal to 0.852 indicating the moderate status; in other words, the hospital has moderate status in terms of utilizing the lean approach. At the next stage, the main obstacles to lead the supply chain of studied hospital to higher levels are mentioned as follows according to the conducted calculations of fuzzy performance importance index as well as the obtained results in the fourth column of table (5): The employee satisfaction, re-engineering of processes, updating the equipment, and performance-based payment system.

CONCLUSION

The lean approach is in fact an innovative management approach which has been successful in health care organizations and it is in fact a powerful concept for improving the processes and eliminating the losses in the system, so that according to Langabeer's view and the modern health care, it focuses on improving the efficiency of health care and simultaneously increases the clinical quality (Langabeer et al, 2009). Following his studies, he argues that there may be an obstacle in the way of improving the efficiency of quality improvement plans in healthcare, lack of clarity of measurement. To overcome this problem in hospitals, this paper has identified the lean production criteria of hospital through the lean principles as the step towards creating the basis for performance evaluation and lean assessment in hospital and this is as a tool to guide the organization to better future. Imam Khomeini Hospital of Kermanshah is evaluated through these criteria. According to the obtained results, the hospital has the moderate lean degree indicating the obstacles in the way of promoting the hospital to higher lean degrees. According to the measurement, the main obstacles, which should be taken into consideration and removed by employees and top manager's cooperation, are as follows: The employee satisfaction, re-engineering of processes, updating the equipment, and performance-based payment system.

Acknowledgements

The authors are thankful to the Imam Khomeini Hospital of Kermanshah, Iran for their kind contribution in providing data for the research work.

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