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Leanness Assessment of Manufacturing Organizations using Fuzzy TOPSIS: A Case Study

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Abstract- *In this case study based paper, the fuzzy TOPSIS is used to assess the current leanness level of three small manufacturing organizations and to generate the order of priority of various issues that the organistion should consider for the successful implemetation of the lean manufactruing strategies. The basic motivation behind this case study is to reduce the number of unsuccessful lean implementations as there are a few success stories of lean implementation reported. The major reasons behind the failure of successful implementation are thelackof the properassessment of the current leanness of organizations and their inability to decide the priority areas from where lean implementation should start. This paper helps to fill these gaps.*

Keywords- *leanness assessment, leanness level, leanness index, fuzzy TOPSIS*

I. INTRODUCTION

In the present era of globalization and mass customization, every organization is trying to maintain its compitive edge over its competiters and maintain/ increase its global presence and leadership. To achieve this, an orgnisation has to find effective solutions to face global challenges like product quality, delivery, cost and so on. To handle those challenges in an effective manner, organizations have to change their existing ways to manage and run their bussinesses. There are several philoshophies and technologies, such as CIM, FMS, lean manufactiuring, agile manufacturing, etc., currently available which can help industries to get competitive advantages by focusing on waste, productivity, quality, flexibility, cost, time, morale, and innovation (Anand and Kodali, 2009). New advanced automated technologies are effective in achieving competitive advantages but they involves a higher initial cost and there is danger for fast obsolescence. On the other side, the lean manufacturing philoshopy, which is based on systematic elemination of waste and improvement in existing technologies, is a cost effective solution to face the current challenges (Yavuz and Akcali, 2007; Bhamu and Sangwan, 2014; Alaskari et al., 2016).

The term lean manufacturing was first coined by John Krafcik in his 1988 article, "Triumph of the Lean Production System". The modern concept of lean production/Lean Manufacturing/management can be traced to the Toyota Production System (TPS), pioneered by Japanese engineers Taiichi Ohno and Shigeo Shingo, as an alternative to the existing mass production system (Bhamu and Sangwan, 2014).

Lean philosophy follows a set of five core principles: (i) accuratly define the need of an end customer, (ii) identify the essential value stream to meet the need, (iii) avoid interruptions in the value flow, (iv) use of a pull production system, and (v) strive for perfection. The systematic implementation of these principles helps in identifying and eliminating the seven types of Non-value added activities, called waste by Ohno. These wastes are transportations, inventory, motion, waiting, overproduction, over-processing, and defects (TIMWOOD) (Alaskari et al., 2016).

Many organizationsadopted and implemented lean concepts successfully and reported excellent results, but there are many failures too. Some of the critical reasons for failures are (i) the unclear understanding of lean parameters, (ii) lack of an effective lean implementation methodology that covers all the vertical and horizontal areas of the organization and (iii) an improper assessment of impact of lean practices (Narayanamurthy and Gurumurthy, 2016).

Over the years, lean researchers identifieda large number of lean performance indicators (LPI)that covers every area of the organization. However, depending on the domain of industries, the importance of these indicatorsvaries. For successful implemetation of the lean philoshophy in an organisation, it is critical to identify the priority order of these indicators for the concirned orgnisation. In this study, total six enablers, thirty criteria and ninety-two sub-criteria are selected for the lean assessment of small to midium size manufacturing organisations.To assess the oranisation leanness using these indicators, fuzzy technique for order of preference by similarity to ideal solution (TOPSIS) is used, whichalso generates the priority order of these parameters for the industry so that the cost and time of the lean implementation can be optimised.

II. LITERATURE REVIEW

A brief description of lean performance indicators and leanness assessment models used by previous researchers are discussed in this section.Prasad (1995) used Just In time (JIT) quality matrix and presented a method for selecting JIT tools for effective lean implementation in organizations. Singh *et al.*, (2006) proposed fuzzy logic based multi-preference, multi-criteria, and multipersondecision-making approach for selecting the Value Stream Mapping (VSM) approach defined by Hines and Rich (1997). Abdulmalek and Rajgopal (2007) used VSM to identify the opportunities for various lean techniques and developed a simulation model to find the "before" and "after" scenarios of a lean implementation. Anand and Kodali (2009) used Analytical network process (ANP), a multi criteria decision making (MCDM) approach, for lean implementations. Zanjirchi *et al*, (2010) measured Fuzzy Leanness Index (FLI) using the model proposed by Lin *et al.*, (2006). The assessment involved three enablers, 10 criteria and 48 sub-criteriathat cover the various lean perspectives of the organization.Vinodh and Chintha (2011) integrated fuzzy Quality Function Deployment (QFD) for identification of lean competitive bases, lean decision domains, lean attributes and lean enablers for the organization.Vinodh *et al.*, (2011) used Analytic Hierarchy Process (AHP), a MCDM to identify the best lean concept between five enablers. Vinodh and Kumar (2012) developed a computerized decision support system (DSS) to assess the multigrade fuzzy leanness index of the selected organization. The model consist of five leanness enablers, 20 leanness criteria, and 59 leanness attributes. Amin and Karim (2013) proposed a time-based mathematical model to evaluate the perceived value of lean strategies as applied to manufacturing waste reduction. Kumar *et al.*, (2013) used Fuzzy TOPSIS to find the closeness coefficient and the ranking order between the firms. Vimal and Vinodh (2013) applied the Artificial neural network (ANN) with fuzzy to assess the leanness of the organization. The network is modeled, trained and simulated using the NN toolbox in MATLAB software. The model consists of five enablers and 30 criteria that cover the various lean perspectives of the organization. Wan and Tamma (2013) used AHP and Rockwell ARENA softwares to develop a LDST for selecting the better sequence of lean tools. Anvari *et al.*, (2014) used the modified VIKOR method for lean tool selection alternatives. Hojjati and Anvari (2014) integrated Simple Additive Weighting (SAW) and TOPSIS to identify the rank of alternatives based on each criterion. Borda method is used for assessment and optimization of the ranking identified by SAW and TOPSIS. Pakdil and Leonard (2014) developed Lean Assessment Tool (LAT) to measures the leanness using eight quantitative performance dimensions: time effectiveness, quality, process, cost, human resources, delivery, customer, and inventory. Vinodh *et al.*, (2014) used , modified fuzzy TOPSIS for prioritizing of lean tools and techniques. Jing *et al.*, (2015) choose the best of alternative based on those evaluation criteria by using improved VIKOR method. Alaskari *et al.*, (2016) developed a methodology contains a quantitative approach to assist manufacturing SMEs in the selection of appropriate lean tools. Vidhyadhar *et al.*, (2016) measured Fuzzy Leanness Index (FLI) using the model prorposed by Lin *et al.*, (2006). After the calculation of FLI, the Euclidian distance method is used for matching Leanness Level (LL) and then fuzzy performance importance index (FPII) is calculated toprioritize order of the alternatives. The same approach is also used by Agarwal *et al.*, (2017). For validate the results of the fuzzy assessment, Adaptive Neuro-Fuzzy Inference System (ANFIS) approach is used. Ruben *et al.*, (2017) integrated lean sustainability system and ANFIS system to assess the lean sustainability index of the selected organization.

III. METHODOLOGY

The objective of the present study is to compare the leanness index (LI) of the selected organizations using fuzzy TOPSIS and providing the priority orders of the LPI. TOPSIS was originally developed by Hwang and Yoon (1981). Solutions from TOPSIS are defined as the points which are simultaneously the farthest from the anti-ideal point and the closest to the ideal point. To consider the uncertainty associated with the mapping of human perception to a number, the integration of fuzzy set theory to TOPSIS was presented by Liang in 1999, which is further improved by Chen (2000), and used by Kumar *et al.*, (2013) for leanness assessment.

For the assessment of LI at least two experts are choosen from three firms to avoid biasness. They are requested to choose an appropriate value for each LPI in lingustict terms based on their experience with the organisation. The selection of linguistic terms and their triangular fuzzy numbers, for importance weight (IW), performance rating (PR), are identical to the values used by Vidhyadhar *et al.*, 2016; Vinodh and Vimal, 2012; Vimal and Vinodh, 2013; Zanjirchi *et al.*, 2010.

The data for the present study was collected by conducting a survey using a large questionnaire. Due to the space limitation, apart of the questionarrie used for this study is given in table (1).

Table 1

Example of LPI code and it explanation

Code	LPI	IW	PR
3	**Implementation of New Manufacturing Strategy (MS) is**		
31	*Implementation of principles of Total Quality Management*		
311	Level of Top management commitment		
312	Level of Quality Improvement program		
313	Use of Quality manual		

Codes given in table 1can be deciphered as single digit numbersrepresent enablers, two digit numbersrepresent criteria and three digit numbersrepresent subcriteria for the corresponding enablers.
Some sample responses of experts for firm B for few LPI and theircorresponding triangular fuzzy numbers are shown in table (2)

Table 2

Example of experts opinion over LPI

code	Expert 1								Expert 2								Expert 3							
	IW				**PR**				**IW**				**PR**				**IW**				**PR**			
311	M	.3	.5	.7	F	3	5	7	H	.7	.8	.9	VG	7	8	9	VH	.8	.95	1	VG	7	8	9
312	FH	.5	.65	.8	G	5	6.5	8	H	.7	.8	.9	G	5	6.5	8	VH	.8	.95	1	G	5	6.5	8
313	FH	.5	.65	.8	G	5	6.5	8	H	.7	.8	.9	F	3	5	7	VH	.8	.95	1	VG	7	8	9

As the data is collected by atleast two experts of each organization, the expert responses are aggregated and normalized using the equations defined by Kumar *et al.*, (2013).A sample of aggregated and normalized opinions (V_{ijk}) is shown in table (3).

Table 3

Example of aggregating and normalizing the LPI

code	Aggregate IW			Aggregate PR			Normalization of Aggregate PR			V_{ijk}		
311	.3	.75	1	3	7	9	.3	.7	.9	.013	.25	.81
312	.5	.8	1	5	6.5	8	.5	.65	.8	.037	.249	.72
313	.5	.8	1	3	6.5	9	.3	.65	.9	.022	.249	.81

After calculating $V_{ijk}$for each LPI,the Fuzzy positive ideal solution (FPIS) (I^+) and Fuzzy negative ideal solution (FNIS) (I^-) are computed using equations (1) and (2).

$$I_{ijk}^{+} = \max\{V_{ijk}\} \qquad (1)$$

$$I_{ijk}^{-} = \min\{V_{ijk}\} \qquad (2)$$

The distance of each lean performance parameter from I_{ijk}^+ and I_{ijk}^- is computed using the Equations (13) and (14).

$$d^{+}(v_{ijk}, I_{ijk}^{+}) = \left\{\frac{1}{3}\sum(v_{ijk}(x) - I_{ijk}^{+}(x))^2\right\}^{1/2} \qquad (2)$$

$$d^{-}(v_{ijk}, I_{ijk}^{-}) = \left\{\frac{1}{3}\sum(v_{ijk}(x) - I_{ijk}^{-}(x))^2\right\}^{1/2} \qquad (3)$$

The closeness coefficient (CC) represents the distance of each lean performance parameter from FPIS and FNIS and is calculated using equation (5).

$$CC = \frac{d_{ijk}^{-}}{\left(d_{ijk}^{-} + d_{ijk}^{+}\right)} \qquad (4)$$

The average of CC shows the relative leanness index of an organization (Kumar *et al*., 2013).

A sample calculation of the sample data shown in table (3) is shown in table (4).

Table 4

Example of calculating CC of sample LPI

Iijk+	Iijk-	(Vijk-Iijk+)^2			d+	(Vijk-Iijk-)^2			d-	CC
0.81	0.0135	0.634412	0.311364	0	0.561479	0	0.056882	0.634412	0.480033	0.4609
0.72	0.0375	0.465806	0.221276	0	0.478568	0	0.044986	0.465806	0.412631	0.463006
0.81	0.0225	0.620156	0.314048	0	0.558034	0	0.051574	0.620156	0.473192	0.458863

The priority order of lean performance indicates is generated by arranging LPI scores (CC in table 4) in ascending order. It is suggested, for successful implementation of lean manufacturing in a industry, that the activity corresponding to the lowest LPI score should be considered first and then the next lowest and so on.Forthe sample example,the priority order of activies for a lean implantation is 313,312 and 311.

IV. CASE STUDY OUTCOME

In this study, three small/medium scale manufacturing industries are chosen randomly located at Jodhpur (Rajasthan). Firm A manufactures submercible pumps, firm B and firm C manufactures different healthcare products. The final leanness indices for these industries as computed by the fuzzy TOPSIS method are tabulated in table (5), from which it can be concuded that firm C is leaner as compared to firm B and firm B is leaner than firm A.

Table 5

Average value of CC of Frms

	Firm A	Firm B	Firm C
$\overline{CC}$	0.4538042	0.4630009	0.4893271

V. CONCLUSION

For a successful implementation of lean manufacturing concepts in various industries, the primary requirement is first assess the current leaness level of the industry and then find the activities priority list in which they are to be considered for the lean implementation. In this paper, a practical use of Fuzzy TOPSIS is illustrated for three manufacturing industries to assess the current leanness levels of the orgnisations and to generate the activities priority order for the industries.

REFERENCES

1. Abdulmalek, F.A. and Rajgopal, J., 2007. Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. International Journal of production economics, 107(1), pp.223-236.
2. Agrawal, R., Agrawal, R., Asokan, P., Asokan, P., Vinodh, S. And Vinodh, S., 2017. Benchmarking fuzzy logic and ANFIS approaches for leanness evaluation in an Indian SME: A case study. Benchmarking: An International Journal, 24(4), pp.973-993.
3. Alaskari, O., Ahmad, M.M. and Pinedo-Cuenca, R., 2016. Development of a methodology to assist manufacturing SMEs in the selection of appropriate lean tools. International Journal of Lean Six Sigma, 7(1), pp.62-84
4. Amin, M.A., and Karim, M.A., 2013. A time-based quantitative approach for selecting lean strategies for manufacturing organizations. International Journal of Production Research, 51(4), pp.1146-1167.
5. Anand, G. And Kodali, R., 2009. Selection of lean manufacturing systems using the analytic network process–a case study. Journal of Manufacturing Technology Management, 20(2), pp.258-289.
6. Anvari, A., Zulkifli, N. And Arghish, O., 2014. Application of a modified VIKOR method for decision-making problems in lean tool selection. The International Journal of Advanced Manufacturing Technology, 71(5-8), pp.829-841.
7. Bhamu, J. and Singh Sangwan, K., 2014. Lean manufacturing: literature review and research issues. International Journal of Operations & Production Management, 34(7), pp.876-940
8. Chen, C.T., 2000. Extensions of the TOPSIS for group decision-making under fuzzy environment. Fuzzy sets and systems, 114(1), pp.1-9
9. Hines, P. And Rich, N., 1997. The seven value stream mapping tools. International journal of operations & production

management, 17(1), pp.46-64.

10. Hwang, C.L. and Yoon, K., 1981. Methods for multiple attribute decision making. In Multiple attribute decision making(pp. 58-191). Springer Berlin Heidelberg.
11. Hojjati, S.M.H., and Anvari, A., 2014. An Integrated MCDM Method in Ranking the Major Lean Practices Based on Four Attributes (pp. 285-298). MAGNT Research report.
12. Jing, S., Niu, Z. And Chang, P.C., 2015. The application of VIKOR for the tool selection in lean management. Journal of Intelligent Manufacturing, pp.1-12.
13. Kumar, S., Singh, B., Qadri, M.A., Kumar, Y.S. and Haleem, A., 2013. A framework for comparative evaluation of lean performance of firms using fuzzy TOPSIS. International Journal of Productivity and Quality Management, 11(4), pp.371-392.
14. Lin, C.T., Chiu, H. And Tseng, Y.H., 2006. Agility evaluation using fuzzy logic. International Journal of Production Economics, 101(2), pp.353-368.
15. Narayanamurthy, G., Narayanamurthy, G., Gurumurthy, A. and Gurumurthy, A., 2016. Leanness assessment: a literature review. International Journal of Operations & Production Management, 36(10), pp.1115-1160.
16. Pakdil, F. And Leonard, K.M., 2014. Criteria for a lean organization: development of a lean assessment tool. International Journal of Production Research, 52(15), pp.4587-4607.
17. Prasad, B., 1995. JIT quality matrices for strategic planning and implementation. International Journal of Operations & Production Management, 15(9), pp.1
18. Ruben, R.B., Asokan, P. And Vinodh, S., 2017. Performance evaluation of lean sustainable systems using adaptive neuro-fuzzy inference system: a case study. International Journal of Sustainable Engineering, pp.1-18.
19. Singh, R.K., Choudhury, A.K., Tiwari, M.K. and Maull, R.S., 2006. An integrated fuzzy-based decision support system for the selection of lean tools: a case study from the steel industry. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 220(10), pp.1735-1749.
20. Vidyadhar, R., Sudeep Kumar, R., Vinodh, S. And Antony, J., 2016. Application of fuzzy logic for leanness assessment in SMEs: a case study. Journal of Engineering, Design, and Technology, 14(1), pp.78-103.
21. Vimal, K.E.K., and Vinodh, S., 2013. Application of artificial neural network for fuzzy logic based leanness assessment. Journal of Manufacturing Technology Management, 24(2), pp.274-292.
22. Vinodh, S. and Kumar Chintha, S., 2011. Application of fuzzy QFD for enabling leanness in a manufacturing organisation. International Journal of Production Research, 49(6), pp.1627-1644
23. Vinodh, S. And Dinesh Kumar, C., 2012. Development of computerized decision support system for leanness assessment using multi grade fuzzy approach. Journal of Manufacturing Technology Management, 23(4), pp.503-516.
24. Vinodh, S. And Vimal, K.E.K., 2012. Thirty criteria based leanness assessment using fuzzy logic approach. The International Journal of Advanced Manufacturing Technology, 60(9-12), pp.1185-1195.
25. Vinodh, S., Shivraman, K.R. and Viswesh, S., 2011. AHP-based lean concept selection in a manufacturing organization. Journal of Manufacturing Technology Management, 23(1), pp.124-136
26. Vinodh, S., Thiagarajan, A. And Mulanjur, G., 2014. Lean concept selection using modified fuzzy TOPSIS: A case study. International Journal of Services and Operations Management, 18(3), pp.342-357.
27. Wan, H.D., and Tamma, S., 2013. Impact of lean tools selection: a simulation study of two assessment approaches. International Journal of Rapid Manufacturing, 3(4), pp.209-227.
28. Yavuz, M. and Akçali, E., 2007. Production smoothing in just-in-time manufacturing systems: a review of the models and solution approaches. International Journal of Production Research, 45(16), pp.3579-3597
29. Zanjirchi, S.M., Tooranlo, H.S. and Nejad, L.Z., 2010, January. Measuring organizational leanness using fuzzy approach. In Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management (pp. 144-156).

