International Business Management 7 (6): 500-507, 2013
ISSN: 1993-5250

Leanness Evaluation in 6 Manufacturing SME's Using AHP and SEM Techniques

[1]M.M. Ravikumar, [2]K. Marimuthu, [3]P. Parthiban and [4]H. AbdulZubar
[1]Faculty of Automation and Robotics, Anna University, Tamil Nadu, India
[2]Department of Mechanical Engineering, Coimbatore Institute of Technology, Coimbatore
[3]Department of Production Engineering,
National Institute of Technology, Tiruchirappalli,
[4]Department of Mechanical Engineering,
Knowledge Institute of Technology, Salem, Tamil Nadu, India

Abstract: Lean is developing into a management tactic which improves the overall standard of an organization. This study aims, at providing a detailed outline of lean implementation helping managers to implement lean in their premises. The factors which affect lean implementing has been carved out of various literature works taking guidelines from experts from both industries and academies. For developing independent and latent variables Structural Equation Modelling is used. For organizing and taking complex decisions used for ranking alternatives analytical hierarchy process technique is used.

Key words: Analytic Hierarchy Process (AHP), lean, management approach, structural equation modeling, viable

INTRODUCTION

Lean manufacturing is one technique that many major organizations have been trying to implement in their premises in order to contain with an volatile global market. Previously TPM was used earlier which emphasizes proactive and preventive maintenance to maximize the operational efficiency of the equipment. But, the core idea of lean is to maximize customer value while minimizing waste in every business and every process. Kriss Precision Engineering, already started implementing the concept of TPM in their unit, where TPM took more time to get positive results (Bhaskar and Ravikumar, 2008). The main objective of lean is to reduce costs without affecting the quality of the product. Lean integrates with discrete manufacturing systems since the integration with continuous manufacturing systems is limited, due to a less urgent need for major development activities (Abdullah and Rajgopal, 2003).

Despite growing recognition, lean implementation is not developing into a successful system which might be due to inadequate knowledge in lean concepts (Behrouzi and Wong, 2011). The only bright spot is the Toyota production systems which aims at eliminating waste (Agarwal *et al*., 2006). This study, investigates the importance of critical success factors in lean implementation. The success factors were obtained after consulting experts from industries and from the academies. SEM is used for loading independent variables for determining latent variables while AHP is used for analyzing complex decision for ranking the organization based on their growths.

Literature review: A large number of studies have been done on lean concept and its various parameters in lean implementation across the globe. Yang and Yu (2010) in his investigation, reveals the road blocks in lean implementation in China. Taj (2008), conducted studies on the various ways of lean implementation in China. Doolen and Hacker (2005) explanatory approach to investigate the effect of leanness in electrical industries in northwest pacific region. Salleh *et al.* (2012) researched on integrating TQM with lean in Malaysia. All these extensive works help to understand the effects of various cultures in different countries. These studies clearly suggest that cultural difference does not play a key role in implementing lean. Various studies have been conducted in different industries. Bayou and de Korvin (2008), investigated the lean technique implemented at Ford and General Motors Automobile industries. Billesbach (1994), used leanness in a process facility industry. Brandon *et al.* (1996) studied how lean practices were transformed in automobile industry. Danesh *et al.* (2013) analysed the performance of organization leanness using simulation. Cagliano *et al.* (2004) performed a cluster analysis to evaluate lean and agile strategies.

Corresponding Author: M.M. Ravikumar, Faculty of Automation and Robotics, Anna University, Tamil Nadu, India

Agrawal *et al*. (2006) used ANP to model the matrices of lean in supply chain. Meade *et al*. (2006) carried out the financial analysis of lean manufacturing using the hybrid simulation technique.

Apart from these, studies have also been carried out to integrate lean approach with various other aspects of manufacturing industry. Yang and Yu (2010), studied the impact of lean manufacturing and environmental management on business performance. Shah and Ward (2003) undertook the study regarding the context, practices and performance of lean manufacturing. Melton (2005) extensively analyzed the benefits of the lean concept in the business process. In this research, researchers have used structural equation modelling as the tool to analyze the critical factors that affect the implementation of lean manufacturing in the SMEs in India and Analytic Hierarchy Process (AHP) technique is used for ranking the companies.

MATERIALS AND METHODS

Structural equation modelling: Structural equation modelling is a larger subject. Relatively brief introductions may be found in (Fox, 1984; Duncan, 1975). Bollena standard volume with most general econometric scripts (Greene, 1993; Judge *et al*., 1985) takes up at least observed-variables structural equation models (Bollen, 1989). SEM is a large sample technology (usually N>200) and the sample size depends on model complexity, the estimation method used and the distributional characteristics of observed variables (Kline, 2005).

Larger models often contain a large number of model parameters demanding larger sample sizes. Sample size for SEM analysis can also be determined based on prior power considerations. There are different approaches to power estimation in SEM (MacCallum *et al*., 1996) on the Root Mean Square Error of Approximation (RMSEA) method (Satorra and Saris, 1985; Yung and Bentler, 1996) on bootstrapping (Muthen and Muthen, 2002). SEM software programs continuously update the goodness-of-fit indices among which some are better than the other appropriate conditions. Generally, the multiple indices are prescribed simultaneously when the overall model fit is evaluated.

Analytic Hierarchy Process (AHP): Among the various MCDM techniques proposed, the Analytic Hierarchy Process (AHP) proposed by Saaty (2008) is very popular and has been applied in a wide variety of areas including planning, selecting a better alternative, resource allocation and resolving conflicts. Given the growing number of AHP applications, a number of papers have been surveying its applications have been published regularly. Zahedi (1986) has provided one of the earliest reviews of AHP. She has outlined four decision steps of AHP and categorized the diverse application fields of AHP in terms of evaluation, selection and prediction. She has also found that all the studies have applied AHP for decision problems with more qualitative data. Most of the applications in her review were theoretical which had not yet been applied in corporate context. Recent overviews have been provided by Forman and Gass (2001). They have discussed applications of AHP for decisions such as choice, prioritization/evaluation, resource allocation, benchmarking, quality management, public policy, health care and strategic planning (Vaidya and Kumar, 2006; Sipahi and Timor, 2010). However, since AHP has been applied in a huge variety of application fields, some recent reviews have focused on the application of AHP in specific fields: Marketing (Wind and Saaty, 1980; Davies, 2001), energy (Pohekar and Ramachandran, 2004), medical and health care decision making Research and Development (R&D) project selection and resource allocation. Wind and Saaty (1980) have reviewed applications of AHP in marketing such as portfolio decisions and desired target portfolio, directions for new product development and generation and evaluation of marketing mix strategies. Davies (2001) has emphasized the used of adaptive AHP for customized marketing decision problems. He reviewed standalone AHP application and recommended that knowledge base to be incorporated in complex marketing decision problems. Pohekar and Ramachandran (2004) have analyzed the applicability of multi criteria decision making methods in 90's published articles related to renewable energy planning, energy resource allocation, building energy management, transportation energy systems, project planning and electric utility planning. A main strength of AHP is its ability to consider subjective opinions of decision-makers. This feature has made it, especially attractive for combining with other methodologies that are usually developed to deal with objective data.

Problem description: In general, successful lean practice in a particular organization depends on the organization characters and not that all organizations should follow the same practices. Larger firm have started implementing lean but small organizations are still struggling to adapt due to various reasons. A few organizations adapted but could not persist with the changes. To make things simple, success factors for better lean implementation have been prescribed by experts from both the industry and academies helping organizations adapt to lean in a better

Table 1: Critical success factors

Success factors	MSME's (6 industries) C1	C2	C3	C4	C5	C6
Effective leadership	5	5	5	5	5	5
Change in organization belief and culture	4	4	4	4	4	3
Employee involvement	1	1	1	1	2	1
Willingness to learn	3	2	3	3	2	2
Company financial capabilities	3	1	1	2	3	2
Commitment of top management	3	4	3	3	3	4
Continual evaluation	1	1	1	1	1	1
Comprehensive education and training	2	2	1	1	2	2
Knowledge sharing	1	2	2	1	2	1
Linking improvement initiatives to business strategy and customer	2	1	1	2	1	2
Facilitator sensei	2	2	1	2	1	1

way. Based on the prescribed factors, a questionnaire covering all aspects has been framed, helping to measure the parameters that block the way to reaching better production techniques, i.e., leanness. The respondents were thoroughly briefed about the parameters.

Nearly 30 critical factors were obtained from experts, consultants and 11 most prominent factors (Table 1) were identified from them. Later ranking were obtained from the organizations after various analyzes in their performance. A structural equation model was developed to examine the critical factors. SEM follows explanatory approach for solving hypothesis by including observed and latent variables. The SEM model can be grouped into two measurement model and the path diagram. Measurement models examine the relationships between each construct and their associated measures while path models examine the relationships between constructs. The SEM model relates the criteria and lean concept. The series of equations is summarized on its configuration. The hypothesized conceptual model with LISREL notations are presented in Fig. 1.

Linear Structural Relations (LISREL) model integrates data analysis and theory construction. The series of equations are summarized on its configuration. As such, researchers need to address the factor structure.

Effective leadership: Strong committed executive leadership is an important requirement for successful lean implementation. Transformational leaders are must in all levels in the company.

H_1: High level of effective leadership helps in higher lean implementation

Change in organizational belief and culture: A multiple case study by Czabke *et al.* (2008), report results of 4 case studies of secondary wood manufacturer from Germany and United States and one of the most important of the factor found was organizational culture and readiness to change.

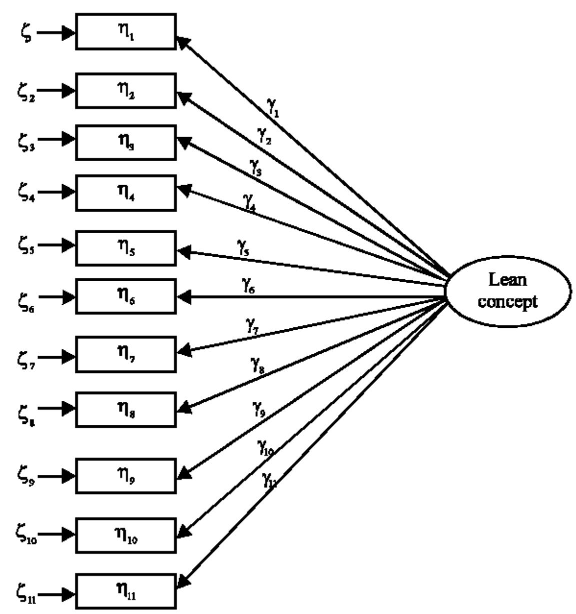

Fig. 1: Conceptual model for lean implementation

H_2: Higher resistance to change leads to lower lean implementation

Employee involvement: Employees working in the process must get involved in analyzing the present state and to develop for the future state. Workers must have sufficient participation.

H_3: Higher employee Involvement leads to higher lean implementation

Willingness to learn: The goal of learning is to provide positive impact outcomes as a result of effective adaptation to environmental changes and improved efficiency in the process of learning.

H_4: Willingness to learn leads to higher levels of lean implementation

Comprehensive financial capabilities: The financial capabilities of the companies are one of the critical factors for successful implementation of lean. Financial resources are needed for employee training programs, external consultants, etc.

H_5: Adequate financial benefits are important for successful lean implementation

Commitment of top management: Consistency in management commitment is emphasized as an important element in effective implementation of changes in organizations (Kotter, 2007). Strong management is must to take the right decisions at the right time.

H_6: Higher commitment of top management helps in higher levels of lean implementation

Continual evaluation: To monitor the result and to take the advantage of the change introduced in the organization it is imperative to measure the performance in the holistic manner.

H_7: Continual evaluation is important for better lean implementation

Comprehensive education and training: Education and training equips the employees with the adapting capabilities. The goal of education and training is to provide positive impact outcomes as a result of effective adaptation to environmental changes and improved efficiency in the process.

H_8: Higher level of education and training leads to higher level of lean implementation

Knowledge sharing: Implementation of lean requires knowledge sharing networks. It also can help break the higher price and input cost cycle.

H_9: Higher knowledge sharing leads to higher levels of lean implementation

Linking improvement initiatives to business strategy and customers: Various experts from industry have led a due emphasis on the fact that thinking development is must for the company to be motivated for the implementation of lean concept in the organization.

H_{10}: Higher thinking development leads to higher level of lean implementation

Facilitator sensei: An expert full time lean consultant is critical for successful lean implementation.

H_{11}: Higher facilitator sensei leads to higher level of success in lean implementation

Questionnaire preparation: An extensive questionnaire which covered various aspects of the critical factors identified was developed. The respondents were required to evaluate the parameters in the categories on the scale of 10 with respect to their importance and their applicability in the implementation of the lean concept in the organization. The respondents were thoroughly briefed about the parameters.

RESULTS AND DISCUSSION

Analysis of survey: The survey was analyzed using structural equation modelling. The SEM structural equation model was developed to get the score of all the 11 critical factors.

Measurement models are used to examine the relationships between each construct and their associated measures and a path model to examine relationships between constructs. The SEM model denotes the relationship between the criteria and lean concept. Researchers can write the series of equations that summarizes its configuration. The factor structure equations are:

$$\begin{gathered} Y_1 = \lambda_1\eta_1 + \varepsilon_1,\ Y_2 = \lambda_2\eta_1 + \varepsilon_2,\ Y_3 = \lambda_3\eta_1 + \varepsilon_3, \\ Y_4 = \lambda_4\eta_1 + \varepsilon_4 \ldots,\ Y_n = \lambda_n\eta_n + \varepsilon_n \end{gathered} \tag{1}$$

And the equation can be written in vector form as:

$$\underset{Y}{\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ . \\ . \\ . \\ Y_n \end{bmatrix}} = \underset{\Lambda}{\begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ . \\ . \\ . \\ \lambda_n \end{bmatrix}} \begin{bmatrix} \eta \end{bmatrix} + \underset{\varepsilon}{\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ . \\ . \\ . \\ \varepsilon_n \end{bmatrix}}$$

Also, the earlier structure can be summarized as:

$$Y = \Lambda_Y\eta + \varepsilon \tag{2}$$

Table 2: Hypothesis testing

Causal path	Hypothesis	Point estimate	t-values	Hypothesis support
Effective leadership → Lean	H_1	0.940	4.87	Yes
Change in organisational belief and culture → Lean	H_2	1.020	5.40	Yes
Employee involvement → Lean	H_3	0.847	4.26	Yes
Willingness to learn → Lean	H_4	0.790	3.34	Yes
Company financial capabilities → Lean	H_5	1.080	5.86	Yes
Commitment of top management → Lean	H_6	1.030	5.46	Yes
Continual evaluation → Lean	H_7	0.960	5.00	Yes
Comprehensive education and training → Lean	H_8	0.900	4.60	Yes
Knowledge sharing → Lean	H_9	0.990	5.12	Yes
Linking improvement initiatives to business strategy and customers → Lean	H_{10}	1.010	5.30	Yes
Facilitator sensei → Lean	H_{11}	0.800	4.02	Yes

Table 3: Weight-age of the critical factors

Weight factors	Values
Effective leadership	0.0990
Change in organization belief and culture	0.1780
Employee involvement	0.0891
Willingness to learn	0.8360
Company financial capabilities	0.1144
Commitment of top management	0.1089
Continual evaluation	0.1023
Comprehensive education and training	0.0946
Knowledge sharing	0.1045
Linking improvement initiatives to business strategy and cost	0.1067
Facilitator sensei	0.0847

Where:

Λ = The factor loadings

ε = Measurement error terms

After determining the face validity through experts to ensure convergence and discriminated validity of the model, the confirmatory factor analysis was performed.

The factor loadings and loading and the respective items Cronbach alpha scores have gained high loadings which indicate a good convergent validity and reliability. Total of 45 questionnaires were distributed in the company, out of which 29 completed questionnaire were received. The values obtained from the questionnaire were received and tabulated in order to obtain the relative weights for the critical factors.

Hypothesis testing: The causal path model was tested by SEM in LISREL version 8.80. The t-values of the variables range from 3.04-5.86, well within the range of expected levels at the level of significance at 0.05. Result of hypothesis has been tabulated in Table 2.

The factors (Latent factors) given by SEM model is considered for the relative weightage of the criteria. The relative weightage of the criteria are found out and tabulated in Table 3.

Analytical hierarchy process procedure: In this method:

- Information is decomposed into a hierarchy of alternatives and criteria

Table 4: Thomas L. Saaty's scale: Pairwise comparison scale

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	2 elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favour 1 element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2, 4, 6, 8	Intermediate values	Used to compromise between 2 judgments

Table 5: Pairwise comparison of alternatives

MSME's	C1	C2	C3	C4	C5	C6
C1	1	3	2	6	5.00	5
C2		1	3	5	3.00	1
C3			1	3	1.00	0.333333
C4				1	0.25	0.2
C5					1.00	0.333333
C6						1

- Information is then synthesized to determine relative ranking of alternatives
- Both qualitative and quantitative information can be compared using informed judgments to derive weights and priorities

Goal:

- Choose the best alternative
- Prioritize the set of alternative
- Set of criteria

AHP procedure:

- Step 1; prioritize the criteria
- Step 2; prioritize the alternatives in terms of each criteria
- Step 3; normalize the prioritization of alternatives

Pairwise comparison scale is shown in Table 4.

Step 1: Pairwise comparison of alternatives. Pairwise comparisons of alternatives are shown in Table 5. After pairwise comparison of alternatives researchers get the value of relative weight for each alternative and researchers have concluded that got more weightage in Table 6.

Step 2: Pairwise comparison in terms of organization structure. A pair wise comparison is made by paring all the MSME against each other is given in Table 7. The relative weight-age obtained for alternatives based on organizational structure are given in Table 8. The relative weight-age of the second MSME is higher whereas the weight-age of the first MSME is the lowest of the 6.

AHP results: After getting relative weights for alternatives based on organization structure, repeat the same procedure for all criteria's and thus we get the result which is shown in Table 9.

The results obtained after performing analytical hierarchy process on the 11 critical success factors in 6 MSME are formulated. The different critical factors are tabulated and the importance given to each by the 6 MSME's.

Lean manufacturing is an integrated manufacturing strategy which is focused on the maximization of capacity and minimization of system variability. The factors (Latent factors) given by SEM model is considered for the relative weightage of the criteria. The relative weightage of the criteria are found out from LISREL and tabulated in Table 10.

Table 10 gives relative weight ages for all the 11 success factors and shows that financial capabilities turned out to be the most important factor industries prefer.

Table 6: Relative weights of alternatives (maximum eigen-value = 6.45738, CI = 0.0914762)

MSME's	Weights (eigen vectors)
C1	0.4180560
C2	0.1887830
C3	0.0955092
C4	0.0358614
C5	0.0816405
C6	0.1801500
Total	1.0000001

Table 7: Pairwise comparison in terms of organization structure

MSME's	C1	C2	C3	C4	C5	C6
C1	1	0.33333	0.5	0.25	0.166667	0.25
C2		1	0.333333	0.25	0.25	0.5
C3			1	0.5	0.25	0.333333
C4				1	1	2
C5					1	3
C6						1

Table 8: Relative weights for alternatives based on organization structure (maximum eigen value = 6.34077, CI = 0.0681547)

MSME's	Weights (eigen vectors)
C1	0.045802
C2	0.076525
C3	0.110862
C4	0.259969
C5	0.336282
C6	0.17056
Total	1

Table 9: AHP results

Factors	C1	C2	C3	C4	C5	C6
Effective leadership	0.418056	0.188783	0.095509	0.035861	0.081641	0.180150
Change in organization belief and culture	0.045802	0.076525	0.110862	0.259969	0.336282	0.170560
Employee involvement	0.033818	0.057967	0.111582	0.298939	0.300323	0.197371
Willingness to learn	0.420986	0.192683	0.073422	0.036824	0.092371	0.183714
Company financial capabilities	0.404035	0.225296	0.071806	0.039213	0.086785	0.172865
Commitment of top management	0.317361	0.185776	0.057455	0.075187	0.154169	0.210053
Continual evaluation	0.418056	0.188783	0.095509	0.035861	0.081641	0.180150
Comprehensive education and training	0.424713	0.191349	0.077909	0.036774	0.077909	0.191349
Knowledge sharing	0.367053	0.161424	0.085058	0.090517	0.105406	0.190543
Linking improvement initiatives to business strategy and cost	0.404035	0.225296	0.071806	0.039213	0.086785	0.172865
Facilitator sensei	0.106217	0.106217	0.286507	0.181334	0.227457	0.092269
Total	3.360132	1.800099	1.137424	1.129691	1.630768	1.941889

Table 10: Weight-ages of the critical factors

Critical success factors	Weights
Effective leadership	0.0990
Change in organization belief and culture	0.1078
Employee involvement	0.0891
Willingness to learn	0.0836
Company financial capabilities	0.1144
Commitment of top management	0.1089
Continual evaluation	0.1023
Comprehensive education and training	0.0946
Knowledge sharing	0.1045
Linking improvement initiatives to business strategy and cost	0.1067
Facilitator sensei	0.0847

Table 11: AHP ranking

MSME's	Rank
C1	1
C2	3
C3	5
C4	6
C5	4
C6	2

Also, using AHP will provide the support to the results. The ranking provided by these techniques shows that there is a better implementation of lean techniques in C1 industries (Table 11).

CONCLUSION

The implementation of lean concept in the manufacturing industries in India is primarily focused in order to reduce the wastage. This waste leads to excess of the working capital and hence, hampers the financial benefit of the organization. Identifying and ranking the critical factors as per their impact on lean implementation in the manufacturing sector is an MCDM problem. The problem has been solved using the technique of Structural Equation Modelling (SEM). Financial benefit has been found out to be the most influencing factor for the implementation of Lean concept. Also, the hypothesis formulated with respect to the 11 identified critical factors has found out to be valid in the causal analysis. The ranking obtained from AHP is useful for the industries to pay their attention on some basic important issues while achieving the prescribed targets. This model paves the way to ease implementation of lean concepts in manufacturing firms not only in India but around the globe.

REFERENCES

Abdullah, F. and J. Rajgopal, 2003. Lean manufacturing in the process industry. Proceedings of the IIE Research Conference, May 18-20, 2003, Portland, OR., USA.

Agarwal, A., R. Shankar and M.K. Tiwari, 2006. Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach. Eur. J. Oper. Res., 173: 211-225.

Bayou, M.E. and A. de Korvin, 2008. Measuring the leanness of manufacturing systems-A case study of ford motor company and general motors. J. Eng. Technol. Manage., 25: 287-304.

Behrouzi, F. and K.Y. Wong, 2011. An investigation and identification of lean supply chain performance measures in the automotive SMEs. Scient. Res. Essays, 6: 5239-5252.

Bhaskar, A. and M.M. Ravikumar, 2008. Improving equipment effectiveness through TPM. Int. Bus. Manage., 2: 91-96.

Billesbach, J.T., 1994. Applying lean production principles to a process facility. Prod. Inventory Manage. J., 35: 40-44.

Bollen, K.A., 1989. Structural Equations with Latent Variables. Wiley New York.

Brandon, G., Mabry and K.R. Morrison, 1996. Transformation to lean manufacturing by an automotive component supplier. Comput. Industrial Eng., 31: 95-98.

Cagliano, R., F. Caniato and G. Spina, 2004. Lean, agile and traditional supply: How do they impact manufacturing performance? J. Purchasing Supply Manage., 10: 151-164.

Czabke, J., E.N. Hansen and T.L. Doolen, 2008. A multisite field study of lean thinking in U.S. and German secondary wood products manufacturers. For. Prod. J., 58: 77-85.

Danesh, S.Y.S., M. Taleghani and H.A. Moridzadeh, 2013. The impact of lean and agile strategy on marketing performance of manufacturing firms. Interdisciplinary J. Contemp. Res. Bus., 4: 987-990.

Davies, M., 2001. Adaptive AHP: A review of marketing applications with extensions. Eur. J. Marketing, 35: 872-894.

Doolen, T.L. and M.E. Hacker, 2005. A review of lean assessment in organisation: An exploratory study of lean practices in Electronics manufacturers. J. Manuf. Syst., 24: 55-67.

Duncan, O.D., 1975. Introduction to Structural Equation Models. Academic Press, New York, ISBN-13: 9780122241505.

Forman, E.H. and S.I. Gass, 2001. The analytic hierarchy process-An exposition. Operat. Res., 49: 469-486.

Fox, J., 1984. Linear Statistical Models and Related Methods. John Willey and Sons, New York, USA.

Greene, W.H., 1993. Econometric Analysis. 2nd Edn., Macmillan, New York.

Judge, G.G., W.E. Gri?ths, R.C. Hill, H. Lutkepohl and T.C. Lee, 1985. The Doctrine and Practice of Econometrics. 2nd Edn., Wiley, New York.

Kline, R.B., 2005. Principles and Practice of Structural Equation Modeling. 2nd Edn., The Guilford Press, New York.

Kotter, J.R., 2007. Leading change: Why transformation efforts fail. Harvard Bus. Rev., 85: 96-103.

MacCallum, R.C., M.W. Browne and H.M. Sugawara, 1996. Power analysis and determination of sample size for covariance structure modeling. Psychol. Methods, 1: 130-149.

Meade, D.J., S. Kumar and A. Houshyar, 2006. Financial analysis of a theoretical lean manufacturing implementation using hybrid simulation modeling. J. Manuf. Syst., 25: 86-98.

Melton, T., 2005. The benefits of lean manufacturing: What lean thinking has to offer the process industries. Chem. Eng. Res. Des., 83: 662-673.

Muthen, L.K. and B.O. Muthen, 2002. How to use a Monte Carlo study to decide on sample size and determine power. Structural Equation Modeling, 4: 599-620.

Pohekar, S.D. and M. Ramachandran, 2004. Application of multi-criteria decision making to sustainable energy planning-a review. Renewable Sustainable Energy Rev., 8: 365-381.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. Int. J. Serv. Sci., 1: 83-98.

Salleh, N.A.M., S. Kasolang and A. Jaffar, 2012. Simulation of integrated total quality management (TQM) with lean manufacturing (LM) practices in forming process using delmia quest. Procedia Eng., 41: 1702-1707.

Satorra, A. and W.E. Saris, 1985. Power of the likelihood ratio test in covariance structure analysis. Psychometrika, 50: 83-90.

Shah, R. and P.T. Ward, 2003. Lean manufacturing: Context, practice bundles and performance. J. Operat. Manage., 21: 129-149.

Sipahi, S. and M. Timor, 2010. The analytic hierarchy process and analytic network process: An overview of applications. Manage. Decis., 48: 775-808.

Taj, S., 2008. Lean manufacturing performance in China: Assessment of 65 manufacturing plants. J. Manuf. Tech. Manage., 19: 217-234.

Vaidya, O.S. and S. Kumar, 2006. Analytic hierarchy process: An overview of applications. Eur. J. Operat. Res., 169: 1-29.

Wind, Y. and T.L. Saaty, 1980. Marketing applications of the analytic hierarchy process. Manage. Sci., 26: 641-658.

Yang, P.G. and Y. Yu, 2010. The barriers to SMEs' implementation of lean production and countermeasures-based on SMS in Wenzhou. Int. J. Innovation Manage. Technol., 1: 220-225.

Yung, Y.F. and P.M. Bentler, 1996. Bootstrapping Technology in Analysis OF Mean and Covariance Structures. In: Advanced Structural Equation Modelling: Technologies and Issues and Techniques, Marcoulides, G.A. and R.E. Schumacker (Eds.). Lawrence Erlbaum, Hillsdale, New Jersey, pp: 195-226.

Zahedi, F., 1986. The analytic hierarchy process-A survey of the method and its applications. Interfaces, 16: 96-108.