Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings 5 (2018) 13406–13412

www.materialstoday.com/proceedings

ICMMM - 2017

Ranking of MUDA using AHP and Fuzzy AHP algorithm

A.Gnanavelbabu[a*] , P.Arunagiri[b]

[a]Research Scholar, Department of Industrial Engineering, Anna University Chennai-600025, Tamilnadu, India
[b]Associate Professor, Department of Industrial Engineering, Anna University Chennai-600025, Tamilnadu, India

Abstract

An analytical approach to the lean waste reduction and classification may have a significant influence on Industrial environment. In order to reduce the lean waste and to find the suitable solutions, waste identification is needed. Analytical Hierarchy Process (AHP) is the one of the way to segregate among the seven types of waste. But Fuzzy AHP is a synthetic extension of classical AHP method when the fuzziness of the decision maker is considered. In this paper analysis of AHP and Fuzzy AHP for the lean waste identification model has been presented. To accredit the proposed model a questionnaire is circulated to 30 number of companies in an international exhibition IMTEX 2015 conducted at Bangalore in India. Mostly multinational companies have participated in the international exhibition in which majority of the respondents belong to automobile industries. Initially AHP is used for determination of weights of lean waste but Fuzzy AHP is better choice to prioritize weights of the various types of lean waste.Both AHP and Fuzzy AHP results are analyzed and compared based on the results. Identification and elimination of the major lean waste leads to productivity improvement.
© 2017 Elsevier Ltd. All rights reserved.
Selection and/or Peer-review under responsibility of International Conference on Materials Manufacturing and Modelling (ICMMM - 2017).

*Keywords:*MUDA; AHP; Fuzzy AHP; Lean Waste reduction; Productivity:

1. Introduction

Lean waste leads to major cost and source of uncertainty due to requirement for the value added product. Lean waste is identified by many manufacturing companies so as to allow for flexible production schedule and one to take advantage of economics of industries. The efficient management of lean waste leads to the reduction of non-value added activities in the production system. Because of huge number of wastages occur in many industries, major

* Corresponding author. Tel.: +91-95511 33779;
*E-mail address:*agbabu@annauniv.edu

2214-7853© 2017 Elsevier Ltd. All rights reserved.
Selection and/or Peer-review under responsibility of International Conference on Materials Manufacturing and Modelling (ICMMM - 2017).

focus is directed towards waste identification in which different lean tools and techniques are used to reduce the particular lean waste. There are seven types of waste named as Transportation, Inventory, Motion, Waiting, Overproduction, over processing and Defects shortly referred to as TIMWOOD. Each category of seven waste should be eliminated with more attention being focused towards the major three waste arising out of the seven waste. Sometimes only one criteria is not a very efficient measure for decision making on lean waste. Therefore, multiple criteria decision making methods are used. Apart from many types of lean waste, the seven waste are taken into consideration. More studies have been conducted on lean sytems and waste elimination in the past 10 years. Many different methods are used to to classify lean waste and taking in to consideration in terms of lean waste, the Multi Criteria Decision Making(MCDM) have been used and developed for the ranking of the criteria.

2. Literature Review

Tarciso et al.[1] stated that qualitative evaluation of lean production is conducted to identify the positive and negative impacts of lean production and also the workers perceptions towards the difference between the old and the new production systems. The various factors considered for the evaluation such as lack of material, available time for pauses, work load, workstation layout, material delivery and housekeeping conditions. Tyson et al.[2] stated the relationship between lean implementation and production cost. They developed a revised framework that reconceptualises the effect of lean on production cost. David et al.[3] considered the various factors such as belief, commitment, work method, communication which have direct impact towards workers perceptions of lean success. Ma ga et al.[4] stated that environmental management practices played a major role to resolve the conflicts between environmental performance and lean manufacturing.

Golam kabir et al. [5] state that relation between the AHP and Fuzzy AHP for multicriteria inventory classification model has been used. The various attributes considered are unit price, annual demand, criticality, last use data and durability. Deif et al.[6] assumed that the lean systems using a new tool called Variability Source Mapping (VSM II) which focuses on reduction of variability across the production system. They also stated that waste elimination is a fundamental way to improve manufacturing system performance. Jian wu et al.[7] stated an interval valued intuistmistic fuzzy AHP method was used for solving MCDM problems. The four criteria considered for the AHP analysis are marketing and sales, customer satisfaction, financial performance and information service.

Sara et al.[8] stated that the relationship between the lean and supply management in terms of the the various conditions of the firms. The questionnaire used in this work for data collection measures the various aspects such as lean management, supply management, environmental practices and performances and control variables. Mustafa et al.[9] stated that MCDM tool such as Fuzzy AHP can be utilized as an approach for supplier selection problems. The various factors considered are quality, origin, cost and delivery after the sales and their weights are estimated using the Fuzzy AHP. Francissco et al.[10] state that the comparison between Fuzzy AHP and Fuzzy TOPSIS for supplier selection were used. The comparative analysis shows that Fuzzy TOPSIS method is more suitable for the supplier selection, change of alternatives, agility, and criteria.

Osman et al.[11] stated that five main criteria were considered for the analysis such as time, cost, quality, safety, and environmental sustainability. These factors are used to select the best project with low risk during project selection. Zeyang song et al.[12] compared the traditional Fuzzy AHP method and the triangular extent Fuzzy approach for the prioritization of factors impacting self-ignition risks. The major factors considered the prioritation are particle size, reactivity of coal, moisture. It have used the fuzzy AHP algorithm for prioritising the characteristics of coal such as particle size, moisture content, sulphur content, wind velocity and radiation. Sylvain et al.[13] stated a Fuzzy AHP methodology was used for the aggregation of opinions from a group of respondents related to sensitive information in a communicating textile. Ajay et al.[14] used a Hybrid Fuzzy AHP approach and DEA to determine the consumer preference using mobile subscribers by network parameters and low tariff scheme. Identification of the different variables and a model preparation is used to bench mark the mobile providers in India.

Sayed Ali Tabatabaei Khoda & Dean kumar[15] state that a combination of risk management process and fuzzy logic has been used for identifying and assessing the risk faced by contractors. The various criteria considered are expertise, financial ability, managers and staff and executive records. Devendra Singh Verma & Ajitabh pateriya

[16] have laid down criteria viz., on-time delivery, product quality, cost, facility and technology, customer need, Professionalism, quality of relationship, performance history and fuzzy AHP is used to prioritise the criteria. Francisco Rodrigues Lima Junior et al.[17] has used the fuzzy AHP and Fuzzy TOPSIS method in the supplier selection decision process from among various suppliers. Shin-Chi Ohnishi & Takahiro Yamanoi et al.[18] has assessed the overall weights of alternatives for double inner dependence structure AHP via fuzzy sets.Based on the literature review discussed in the previous content this work focus on evaluation of lean waste in terms of AHP and Fuzzy AHP results.

2.1. Application of AHP and fuzzy AHP models

To accredit the proposed model a questionnaire is circulated to 30 number of companies in an international exhibition IMTEX 2015 conducted at Bangalore in India. Mostly multinational companies have participated in the international exhibition in which majority of the respondents belong to automobile industries. Initially AHP is used for determination of weights of lean waste but Fuzzy AHP is better choice to prioritize weights of the various types of lean waste.

2.2. Analytical Hierarchy Process

AHP is a MCDM approach and was introduced by Satty 1980. The main purpose of the AHP is to break down a problem in to smaller constituent parts. By diluting the problem, the decision maker can focus on limited number of items. The two phase of the AHP are evaluation of components in the hierarchy and the design of hierarchy. AHP is mainly used for the comparison of decision elements which are different to quantity and for the MCDM process. AHP is a computational technique for decision making. It is for making decision as a team. It involves in ranking of decision elements and then making comparison between pair of cluster. This gives a weighting for each element within a level of hierarchy and to determine the weights of criteria using AHP for the seven types of lean waste. The procedure for AHP is shown in the figure 1 below.

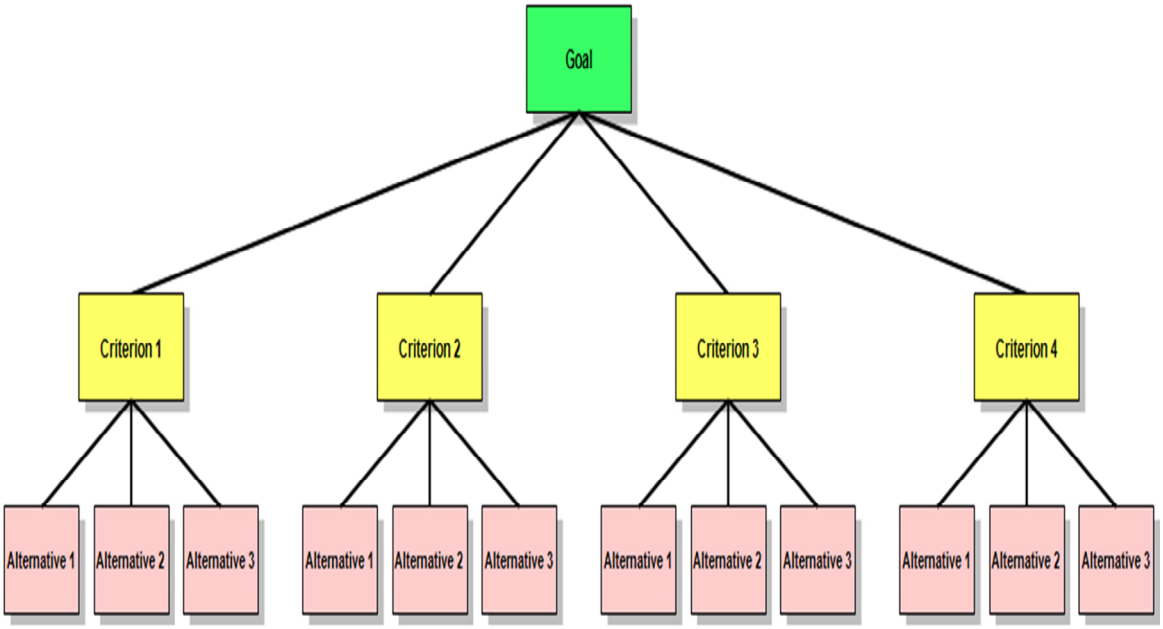

Figure1. Procedure involved in AHP

2.3. Shortcomings of Analytical Hierarchy Process

AHP has some shortcomings as follows:

a. The AHP method is used for making crisp decision.
b. The AHP method deals with an unbalanced scale of judgment.
c. AHP method is rather imprecise for the ranking of alternatives
d. The selection and preference of decision-makers have high influence on AHP results.
e. The decision-maker evaluates the alternatives based on ambiguity and multiplicity.
f. Human assessment on qualitative attributes is always subjective and imprecise.

Assessment on qualitative attributes is always subjective and therefore imprecise. Therefore, Conventional AHP seems inadequate to answer decision maker's requirements. The weighting for each element with a level in the hierarchy and a consistency ratio is very much useful for checking the consistency of the data. The consistency ratio of the various values is tabulated table 1 below.

Table 1. Randomly Generated Consistency Index for different size of matrix

N	1	2	3	4	5	6	7	8	9	10
R.I	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The acceptable Consistency Ratio(CR) range varies according to the size of matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, n>= 5. If the value of CR is equal to, or less than that value, it indicates that the evaluation within the matrix is acceptable or a good level of consistency in the comparative judgments represented in that matrix. Any excess of CR over accepted value indicated the presence of inconsistency of judgments within the matrix and the need for an evaluation process.

2.4. Fuzzy Analytical Hierarchy Process

In order to analyse the kind of uncertainty respondent's preference, fuzzy values could be associated with the pair wise comparison of AHP. A variant of AHP, called Fuzzy AHP, comes into implementation in order to overcome the complexity of the AHP. The fuzzy AHP produces more accurate results for the decision making process. According to the responses on the question form, the corresponding triangular fuzzy values for the linguistic variables are placed and the pair wise comparison matrix is constructed. Subtotals are calculated for each row of the matrix and new (l, m, u) value is obtained. To evaluate all Triangular Fuzzy Number (TFN) for each criterion, li/Σli, mi/Σmi, ui/Σui, (i=1,2,..., n) values are calculated and used as the latest Mi(li, mi, ui) set for criterion Mi in the remaining process. The membership function is defined as the degree of possibility of the value for certain criteria, the minimum degree of possibility of the situations is greater than the others and the weight of this criterion estimated before normalization. After obtaining the weights for each criterion, they are normalized and called the final importance degrees for the hierarchy level. Most of the studies performed by using different criteria such as Dickson [19] used 23 critieria and cheraghi[20] used 13 criteria for the prioritize of the alternatives criteria will increase as market globalization quickens.

3. DETERMINATION OF WEIGHTS USING AHP

The lean waste identification was designed judgment about importance of selected criteria for AHP and FAHP models. The questionnaire was completed by 30 experts and all are belonging to the various employees of industries during the exhibition IMTEX 2015. To aggregate the group decision arithmetic mean operation are used for both AHP and Fuzzy AHP algorithms. Opricovic and Tzeng [21] stated that a comparison with other aggregation methods as well as prioritization algorithms like in could be of advantage. The pair wise comparison matrix of 7 types of lean waste with respect to the other relevant waste is stated in the table 2 below.

Table 2.Pair wise comparison matrix of 7 types of lean waste

Type of waste	OPD	TP	WA	MO	DE	IN	OPG
Overproduction	1	1	0.2	0.25	1	0.25	1
Transportation	1	1	0.5	0.5	0.5	0.5	0.5
Waiting	5	2	1	1	1	2	2
Motion	4	2	1	1	0.5	3	0.5
Defects	1	2	1	2	1	2	1
Inventory	4	2	0.33	0.33	0.5	1	1
Overprocessing	1	2	2	2	1	1	1

The lowest value of the above matrix is 0.2. The randomized index value ranges from 0.58 -1.59 and the average is 1.32. The CI value is 0.137475. The CI/RI value is 0.10413 which is obtained from the fourth iteration. The AHP results are validated with consistency check of 10% weightage. The weight of each factor shown in figure 2 show that waiting is major waste occurs during production with 20.9%. Transportation is considered as a second major waste with 19%. Inventory & Motion ranked 3 and 4 with the percentage of 16.50 and 15.60%. Defects ranked 5 with 11.50%. The Overproduction and Overprocessing ranked 6 and 7 respectively as shown in the belowfigure 2.

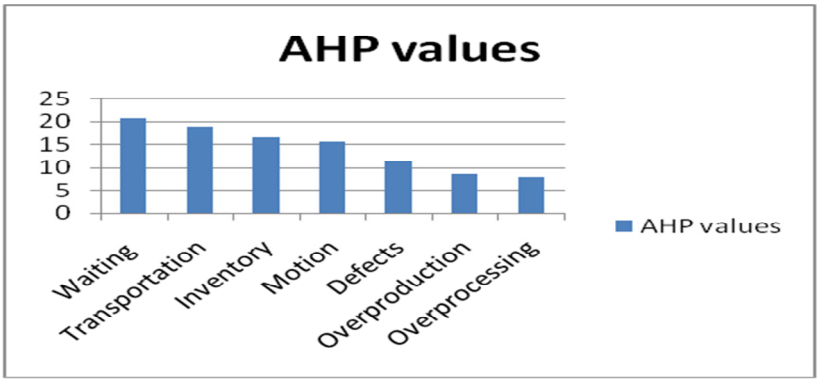

Figure 2: AHP values

4. Determination of Weights Using Fuzzy AHP

The AHP results are compared with Fuzzy AHP results. The evaluations are done based on the Fuzzy AHP algorithm for the seven types of lean waste identification. Table 3 shows the aggregated fuzzy pairwise comparison of the lean experts. The matrix shown in table 2 and the value was used to measure the importance for each criteria based on Chang analysis.The assumption of TFN can be found frequently in literature which facilitates fuzzy arithmetic calculations as stated in [22].

Table 3 Fuzzy comparison matrix of the attribute of Fuzzy AHP model

Type of waste	OPD	TP	WA	MO	DE	IN	OPG
Overproduction	1,1,1	0,0,3.3	1.4,1,1	2,1.4,1	0,0,303	2,1.4,1	0,0,3.3
Transportation	0,0,3.3	1,1,1	0,3.3,2	0,3.3,2	0,3.3,2	0,3.3,2	0,3.3,2
Waiting	0.7,1,1	0,0.3,0.5	1,1,1	0,0,3.3	0,0,3.3	0,3.3,0.5	0,0.3,0.5
Motion	0.5,0.7,1	0,0.3,0.5	0,0,3.3	1,1,1	0,3.3,2	0.2,0.5,0.8	0,3.3,2
Defects	0,0,0.3	0,0.3,0.5	0,0,3.3	0,0.3,0.5	1,1,1	0,0.3,0.5	0,0,3.3
Inventory	0.5,0.7,1	0,0.3,0.5	0,3.3,2	5,2,1.2	0,3.3,2	1,1,1	0,0,3.3
Overprocessing	0,0,0.3	0,0.3,0.5	0,3.3,2	0,0.3,0.5	0,0,0.3	0,0,0.3	1,1,1

The inconsistency of TFN can be checked and the consistency ratio (CR) has been calculated. The results for eigen value of matrix lmax=5 and the consistency index = 0.1374. The ratio of CI/RI value is 0.10413. The randomly generated consistency index RI =1.32 and the CR is 0.10413. As the CR is greater than 0.1 then the level of consistency was stored in comparison matrix. The degree of possibility of Su is calculated. It is represented by V (Su>=Sa).The normalized value of this vector decides the priority weights of each criterion. The normalized weight vector are calculated as w = (0.4395, 0.4423, 0.3936, 0.3487, 0.4123, 0.20313). The calculated Fuzzy AHP values for these weights are given in the figure 3.

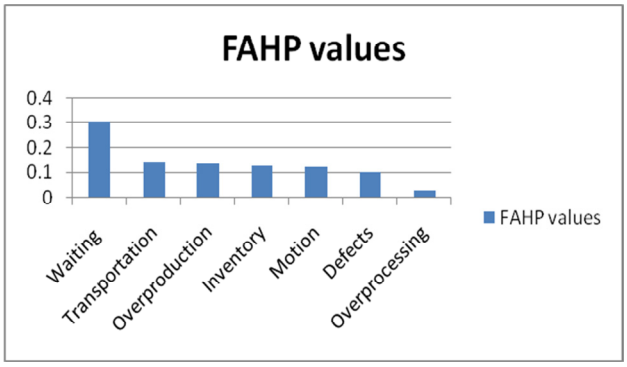

Figure 3. Fuzzy AHP Values

5. Results and Discussions

In this work, the comparative analysis of AHP and fuzzy AHP is used for the lean waste identification. Using AHP, the normalized weight of each attributes shown in figure 1 which states that waiting time with the value of 0.3083 has higher priority than any other criteria. Identification of major lean waste using weighted average was found out[23]. Moreover, major lean tools were found out using the former algorithms as stated in [24, 24]. Fuzzy has been employed for showing the comparison between the subject criteria because the decision maker feels comfortable. Using changs extent analysis, the normalized weight of each lean waste is shown in figure 2 above.

Waiting time has high priority than other types of waste. The results of the AHP and FAHP are given in table 3 below. Using AHP and FAHP model, the major lean waste out of seven types of waste are identified. The evaluations are certain and the classical method should be preferred. If the evaluations are not certain fuzzy method should be preferred. In recent years, the characteristic of information and decision maker and the probable deviation is integrated for decision making process. Due to this reason, for each decision making method, a fuzzy results developed and the fuzzy AHP is a natural result of this need to identify the major lean waste.

Table: 3 Comparison of AHP and Fuzzy AHP results

Type of waste	OPD	TP	WA	MO	DE	IN	OPG
AHP value	8.6	19.0	20.9	15.6	11.5	16.5	8.0
Fuzzy AHP value	13.55	14.31	30.83	12.14	10.13	12.73	2.9

6. Conclusions

In today production and business environment, an organization must reduce the lean waste at an appropriate method. Because the customer pay for the non-value added activities used in the industries, many researchers devote themselves to identify the major quality tools, lean waste and its tools. This work focused on the identification of major lean waste and to rectify the same. In this research a comparative analysis of AHP and Fuzzy AHP for multi criteria lean waste identification model has been presented. AHP is one of the most commonly used techniques for any critical factors. The uncertainty of fuzzy environment and the fuzzy numbers have been used for

the evaluation due to the deviation of decision makers. The Fuzzy AHP approach proved to be easiest method for MCDM problems. Fuzzy AHP techniques used to synthesize the statement of decision makes to identify major lean waste .The AHP value obtained for waiting waste is 20.9, Transportation is 19.0, Motion is 15.6 which leads to the major waste. The value of AHP for inventory is 16.5, defects is 11.5 ,overproduction is 8.6 and over processing is 8.0.The Fuzzy AHP value for waiting waste is 30.83, transportation is 14.33 ,Overproduction is 13.55, inventory is 12.35, Motion is 12.14, defects is 10.13 and overproduction is 20.9. Both the AHP and Fuzzy AHP values are compared and major three wastes are needed to be reduced to improve the production system. The identification of major lean waste are used to identify the major waste occurs in the production activities, to improve the production efficiency and to improve the quality, profit and reduction of defects in the industrial environment.

References

[1] Tarcisio Abreu Saurin and Cleber Fabricio Ferreira "The impacts of lean Production on working conditions: A case study of a harvestor assembly line in Brazil" International Journal of Industrial Ergonomics, Vol. 39, pp. 403, 2009

[2] Tyson R. Browning and Ralph D. Heath "Reconceptualizing the effects of lean on production costs with evidence from the F-22 program" Journal of Operations Management, Vol. 27, pp. 23–44, 2009

[3] David Losonci, Krisztina Demeter, and Istvan Jenei. "Factors influencing employee perceptions in lean transformations" International Journal Production Economics, Vol. 13, pp. 30-43, 2011.

[4] Ma Ga (Mark)Yang, Paul Hong and Sachin B.Modi "Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms" International Journal of Production Economics, Vol. 129, pp. 251–261, 2011.

[5] Golam Kabir and M. Ahsan Akhtar Hasin "Comparative analysis of AHP and fuzzy AHP models for multicriteria inventory classification" International Journal of Fuzzy Logic Systems, Vol.1, No.1, pp 1-16, 2011.

[6] Deif A "Assessing lean systems using variability mapping" Procedia CIRP, Vol. 3, pp. 2-7, 2012.

[7] Jian Wu, Hai–bin Huang, Qing wei cao, "Research on AHP with interval-valued intutionistic fuzzy sets and its application in multicriteria decision making problems" Applied mathematical modeling, Vol 37, pp. 9898-9906, 2013.

[8] Sara Hajmohammad, Stephan Vachon, Robert D. klassen, Luri Gavronski, "Reprint of lean management and supply management: their role in green practices and performance" Journal of cleaner production, Vol. 56, pp. 86-93, 2013.

[9] Mustafa Batuhan Ayhan "A fuzzy ahp approach for supplier selection problem: a case study in a gear motor company" International Journal of Managing Value and Supply Chains, Vol.4, No. 3, 2013.

[10] Francisco Rodrigues Lima junior, lauro osiro, luiz cesar Ribeiro Carpinetti, " A comparison between fuzzy AHP and Fuzzy TOPSIS methods to supplier selection", Applied soft computing, Vol. 21, pp. 194-209, 2014.

[11] Osman Taylan, Abdallah O. Bafail, Reda M.S. Abdulaal, Mohammed R. Kabli, "Construction projects selection and risk assessment by fuzzy AHP and TOPSIS methodologies", Applied soft computing, Vol. 17, pp. 105-116, 2014.

[12] Zeyang Song, Hongqing Zhu, Guowei Jia, Chaonan He, "Comprehensive evaluation on self-ignition risks of coal stockpiles using fuzzy AHP approaches", Journal of loss prevention in the process industries, Vol. 32, pp. 78-94, 2014.

[13] Synlvain Kubler, Alexandre Voisin, William Derigent, Andre Thomas, "Group Fuzzy AHP approach to relevant data on communicating material" Computers in Industry, Vol. 65, pp. 675-692, 2014.

[14] Ajay kumar, Ravi Sankar, Roma Mitra Debnath, "Analysing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study" Telematics and Informatics, Vol. 32, pp. 447-462, 2015.

[15] Seyed Ali Tabatabaei Khodadadi & Dean kumar, "Contractor selection with risk assessment by using AHP fuzzy method", International journal of advances in engineering and technology, Vol. 5(2), pp. 311-318.

[16] Devendra Singh Verma & Ajitabh pateriya "Supplier Selection through Analytical Hierarchy Process: A Case Study in Small Scale Manufacturing Organization" International Journal of Engineering Trends and Technology, Vol.4 (5), 2013.

[17] Francisco Rodrigues, Lima Juniora, Lauro Osirob, Luiz Cesar & Ribeiro Carpinettia, "A Comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection" Applied Soft Computing, Vol. 21, pp.194–209, 2014.

[18] Shin-ichi Ohnishi & Takahiro Yamanoi, "On fuzzy priority weights of AHP for double inner dependence structure", Procedia computer science, Vol. 35, pp. 1003-1012, 2014

[19] Dickson, G.W., (1966) "An Analysis of Vendor Selection Systems and Decision". Journal of Purchasing Vol.2(1), pp.5-17.

[20] Cheraghi, S. H., Dadashzadeh,M., & Subramanian, M., "Critical success factors for supplier selection: An Update", Journal of Applied Business Research, Vol 20(2), pp. 91–108, 2004.

[21] Opricovic, S., & Tzeng, G.-H., "Defuzzification within a multicriteria decision model", International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Vol. 11 (5), pp. 635-652, 2003.

[22] Mikhailov, L,"Deriving priorities from fuzzy pairwise comparison judgements" Fuzzy Sets and Systems, Vol. 134, pp. 365-385, 2003.

[23] Arunagiri, P and Gnanavelbabu, A.,"Identification of major lean production waste in automobile industries using weighted average method," Procedia Engineering, Vol. 97, pp. 2167–2175, 2014.

[24] Arunagiri, P and Gnanavelbabu, A., "Identification of high impact lean production tools in automobile industriesusing weighted average method" Procedia Engineering, Vol 97, pp. 2072 – 2080, 2014.

[25] Arunagiri P and Gnanavelbabu A, "Identification of Major lean waste and its Contributing Factors using the Fuzzy Analytical Hierarchy Process" (2016), Transactions of the Canadian Society for Mechanical Engineering, Vol.40, No.3, pp-371-382.