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Lean Manufacturing based Interpretive Structural Modeling using Fuzzy Analytical Hierarchy Process

Arul Thayammal Ganesan [1]
[1]Professor, Department of Mechanical Engineering,
St Mary's Engineering College, Deshmukhi, Pochampalli, Nalgonda District,
Hyderabad -508 284, Telangana, India.

***Abstract*:- Manufacturing industries are the very source country's development which spaces economic growth are impolite, absorbs and recreates the same several times over in the economy. To improve capacity and competitiveness and bring down waste, lean manufacturing is a genial aspect tool. Even though large-scale sectors have started implementing it, the Indian Micro, Small and Medium-Enterprises (MSMEs) still find it hard to implement. In this novel research offered the success factors that are critical for more successful lean implementation. Using Interpretative structural modeling and structural equation modeling the strength of each factor are determined. The outcome of research work clearly indicates that Strong Management and Leadership (SML), Electronics and Communication of the Transformation process and goals (EC), Skills and Expertise (SE), and Employee Trust (TE) are at the higher level of importance in the ISM model considered. It is noted that Plan and Strategy (PS), Education and Training (ET), Customer Focus (CF) and Thinking Development (TD) are relatively lower level preference. PS has the highest driving power and EC has the least dependence powers. Based on eleven criteria, SML is the best for all Indian MSMEs. The proposed model evaluated using Analytical Hierarchy Process (AHP), fuzzy AHP, are made to find the extent of Lean Manufacturing (LM) which has been implemented for successful performance in six Indian MSMEs**

Keywords: Lean Manufacturing, Strong Management Leadership, Analytical Hierarchy Process, Interpretive Structural modeling

NOMENCLATURE

MCDM	**Small and Medium-Enterprises**
AHP	**Analytical Hierarchy Process**
ISM	**Interpretive Structural Modeling**
MISM	**Modified Interpretive Structural Modeling**
SSIM	**Structural Self-Interaction Matrix**

1 INTRODUCTION

In various real life problems, Small and Medium-Enterprises (MCDM) plays an optimal note. In one way or the other local or federal government industry or business activity is involved in the evaluations of a group of alternatives in terms of a set of decision measure. These measures are conflicting to one another often. It is very expensive to collect the pertinent data often. J.Warfield in 1974 planned philosophy to investigate the complicated social and financial system. It is a computer-based learning method during which specific people or teams develop a map of the complicated relations between several criteria concerned in any things [11]. the essential plan is to resolve a sophisticated system into many subsystems (elements) and construct a construction structural model by exploitation the expert's sensible experiences and data. The concepts involve taking a set of criteria, comparing it with those measure in the dual relation defined, and construct a reachability matrix from the companions [1, 9].

In many engineering industrial applications, the ultimate call depends on the evaluations of variety of alternatives in terms of variety of criteria of any downside, which can become sophisticated once the factors is denoted in several units or the pertinent information area unit dissimilar to be measured [2]. In dealing with this kind of decision problem, the AHP is a cluster based resolution making technique which guides the decision makers to find the best criteria that meets their goal [10]. By formulating a series of one on one comparison it provides one framework to decrease qualitative and quantitative difficult constraints. It does not only provide justification for the choice of the best alternatives. Fuzzy AHP: To solve multiple-criteria decision making problem in both academic research and industrial practice, generally, the AHP has been used. But because of the vagueness and uncertain with a conventional AHP, it may not capture accurately the decision makers judgments. Therefore, to compensate for this deficiency in the conventional AHP, fuzzy logics is initiated into the pair-wise assessment in the AHP. This is termed as fuzzy AHP.

In several engineering industrial applications, the final decision depends on the evaluations of a number of alternatives in terms of a number of criteria of any problem, which may become complicated when the criteria is denoted in different units or the pertinent data are difficult to be quantified[2]. In dealing with this kind of decision problem, the AHP is a group decision making technique which guides the decision makers to find the best criteria that meets their goal [10]. By formulating a series of one on one comparison it provides one framework to reduce qualitative and quantitative complex constraints. It does not only provide justification for the choice of the best alternatives. Fuzzy AHP: To solve multiple-criteria decision making problem in both academic research and industrial practice, generally, the AHP has been used. But because of the vagueness and uncertain with a conventional AHP, it may not capture accurately the decision makers judgments. Therefore, to compensate for this deficiency in the conventional AHP, fuzzy logics is introduced into the pair-wise comparison in the AHP. This is termed as fuzzy AHP.

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2 BACKGROUND

Due to the increasing competition, supplier selection attained the state of highest importance for most of the companies. Noorul & Kannan [7] developed a supply chain for its five manufacturing products. A few issues emerge because of picking the best provider and for the association between the criteria and sub-criteria. In light of the master study, the criteria and sub-criteria are picked. A poll comprising of the elements was set up for overview. To rank the criteria and sub-criteria utilizing the provider choice and rank the connection among those utilizing Interpretive Structural Modeling (ISM) is a definitive point.

Parthiban et al. [8] made a new attempt to solve the questions on the interactions between the criterion, which criteria influences the supplier selection more, finding the best and weak supplier and providing performance improvement methods to enhance the quality for considering the associations between the criteria and organizing them utilizing the Modified Interpretive Structural Modeling (MISM). Yang et al.[12] (2008) adopted interpretive structural modeling to determine the relationships among the sub-criteria. To compute the relative weights for each criteria fuzzy analytical hierarchy process is used. The huge yet complex to comprehend and organizes the interrelationships between singular hazard components. On analyzing all the risks in a company as an integrated system, to compute asset, a learning technique ISM is utilized to build a basic connection and characterize those hazard interrelationships.

Gorvett and Liu [6] embraced ISM procedures to overview firms general hazard profile is a superior way. By a few criteria's and sub-criteria's the provider basic leadership process is in this way turned out to be a muddled procedure, which may fluctuate crosswise over various item classes and circumstances. Cannon and Perreault [3] proposed and dissected the interrelation of criteria which is utilized to choose the provider

SML -- Strong Management & Leadership
OC -- Organizational Culture
TE -- Employee Trust
SE -- Skills and Expertise
FC --Financial Capabilities
EC --Effective Communication

3.2 Structural Self-Interaction Matrix

In building up the calculated relationship among the criteria, ISM philosophy suggests the utilization of ex-spunky sentiments in light of different administration systems. In this examination, specialists from the business are counseled for recognizable proof of the applied relationship among the elements for the provider determination. To mean the bearings of the connection between the variables (p and q) the accompanying documentations are utilized.

V: Criterion p will help alleviate criterion q;
A: Criterion q will be alleviated by criterion p;
X: Criterion p and q will help achieve each other; and
O: criterion p and q are unrelated

who decide the ecological performance utilizing ISM and AHP utilizing a vehicle organization in the southern piece of India the adequacy of the ISM and AHP model is characterized.

3 PROPOSED MODEL

The ISM concept was basically introduced by Warfield in 1974. It was emphasized that ISM approach facilitates classification and directions of the complex relationships among components of a socioeconomic system. ISM deciphered is connected on the gathering's judgments and choices, regardless of whether and how the framework components are connected. It depends on relationship establishment and the last structure is expelled from an unpredictable arrangement of frameworks. It can likewise be named displaying since the last relationship is said in a divide graphical model. Several steps involved in the ISM techniques are as follows. To identify the key element based on the experts survey. To establish a conceptual relationship in between the elements in reference to which parts of elements are to be examined. To build a Structural Self-Interaction Matrix (SSIM) of components are meaning the match savvy connection between the components. To build up a reachability network from the Structural Self-Interaction Matrix (SSIM) by twofold relations and assess the framework for transitivity, which is a fundamental presumption in ISM that states ―If component A is identified with B and B is identified with C, at that point An is identified with C from the matrix level segment of the component are made. In light of the ISM show the supplanting levels ought to be finished. To figure the standardized weights for the components the model is investigated to check for irregularity.

3.1 Identification of the Performance Criteria

By taking opinions from the industrial experts, the performance criteria are identified. The factors, which are finalized for the study, are mentioned below

CF --Customer Focus
PM --Performance Measures
ET --Education and Training
PS --Plan and Strategy
TD --Thinking Development

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Table-1. Structural Self-Interaction Matrix illustrating Linguistic Variables for the power of each Criterion

	CF	TD	PS	ET	PM	EC	FC	SE	TE	OC	SML
SML	V	A	V	V	A	V	A	O	X	A	-
OC	O	V	X	O	O	V	V	O	X	-	
TE	O	A	O	X	O	A	V	A	-		
SE	V	O	X	V	A	V	V	-			
FC	V	A	O	A	V	O	-				
EC	V	A	A	V	O	-					
PM	V	A	O	A	-						
ET	O	O	A	-							
PS	V	X	-								
TD	O	-									
CF											

Table 2.Initial Reachability Matrix illustrating Driving Powers and Dependence Performance Criterion

	CF	TD	PS	ET	PM	EC	FC	SE	TE	OC	SML	RANK
SML	1	0	1	1	0	1	0	0	1	0	0	5
OC	0	1	1	0	0	1	1	0	1	1	1	7
TE	0	0	0	1	0	0	1	0	1	1	1	5
SE	1	0	1	1	0	1	1	0	1	1	1	8
FC	1	0	0	0	1	0	0	1	0	1	0	4
EC	1	0	0	0	1	1	1	1	0	0	0	5
PM	1	0	0	0	0	1	0	0	0	1	0	3
ET	0	0	0	1	1	1	1	0	1	0	0	5
PS	1	1	0	1	1	1	1	1	0	1	0	8
TD	0	0	1	1	1	0	1	0	1	0	1	6
CF	0	1	0	0	0	1	1	1	0	1	0	5
RANK	6	3	4	6	5	8	8	4	6	7	4	61/61

3.3 Reachability Matrix

The SSIM is transformed into a binary matrix on substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1 and 0 are the following:

- If the (p, q) entry in the SSIM is V, then the (p,q) entry in the reachability matrix becomes 1 and the (q, p) entry becomes 0.
- If the (p, q) entry in the SSIM is A, then the (p,q) entry in the reachability matrix becomes 0 and the (q, p) entry becomes 1.
- If the (p, q) entry in the SSIM is X, then the (p,q) entry in the reachability matrix becomes 1 and the (q, p) entry also becomes 1.
- If the (p, q) entry in the SSIM is O, then the (p,q) entry in the reachability matrix becomes 0 and the (q, p) entry also becomes 0.

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3.4 Hierarchy of Factors

Figure1. Performance factors in a hierarchy

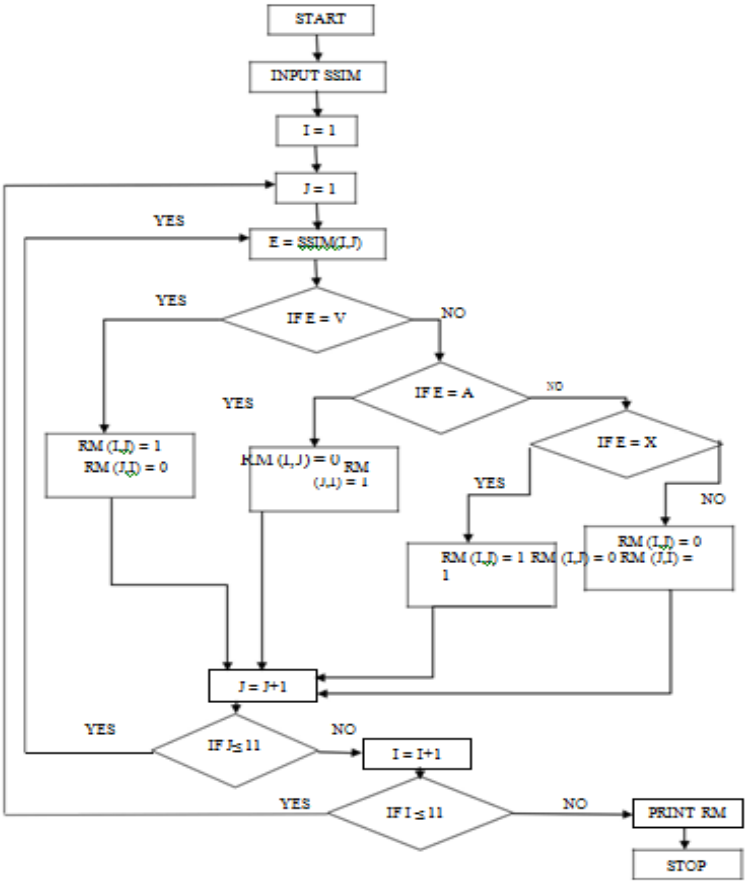

Fig.1. Hierarchy of Factors

3.5 Final Reachability matrix

The transitivity is checked for conclusive reachability matrix utilizing the connection as takes after: ―If A is identified with B and B is identified with C, at that point A is identified with C

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Table 3. Final Reachability Matrix Showing Driving Powers and Dependence Power for each Criterion

	CF	TD	PS	ET	PM	EC	FC	SE	TE	OC	SML	DRIVING POWER
SML	1	0	1	1	0	1	0	0	1	0	1	6
OC	0	1	1	0	0	1	1	0	1	1	1	7
TE	0	0	0	1	0	0	1	0	1	1	1	5
SE	1	0	1	1	0	1	1	0	1	1	1	8
FC	1	0	0	0	1	0	1	1	0	1	0	5
EC	1	0	0	0	1	1	1	1	0	0	0	5
PM	1	0	0	0	0	1	1	0	1	1	0	5
ET	0	0	0	1	1	1	1	1	1	0	0	6
PS	1	1	0	1	1	1	1	1	1	1	0	9
TD	0	0	1	1	1	0	1	0	1	0	1	6
CF	0	1	0	0	0	1	1	1	0	1	0	5
DEPENDENCE POWER	6	3	4	6	5	8	10	5	8	7	5	67/67

3.6 Analytical Hierarchy Process implementation

AHP is characterized a numerical basic leadership method which permits thought of both subjective and quantitative parts of choices [4]. Differently sub-criteria providing justification for the choice, it allows the decision makers to select the best alternatives

AHP calculation is performed in three phases:

(1)Building of the hierarchy

(2)Assessment of pair-wise comparison matrices

(3)Estimation of priority weights of alternative

3.6.1 Construction of the Hierarchy

1. Identify the objective of the issue
2. Identify the criteria and sub criteria which bolster the satisfaction of the ensuing levels
3. Identify the elective recommended to satisfy the objective all levels following the criteria levels.

3.6.2 Evaluation of the Pair-wise Comparison

Estimate the judgment weight for every examination table for instance a scale from 1 to 5 is utilized to differentiate the significance of given rule contrasted and each other.

Table 4. Rating scale to balance one standard over another

Response	Grade
Excellent	5
Good	4
Normal	3
Satisfied	2
Unsatisfied	1

Ranking possible with the pair of alternatives results are done in several square matrixes for each criterion. The performance factor obtained from 6 industries based on the weights of linguistic variables is shown in Table 5. Figure 2. Plotted below, shows each criteria performance difference through various color lines. Also the normalized weights obtained for the performance of 6 industries is shown in Table 6 for each criterion value.

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Table 5.Linguistic Variable Weights for six Suppliers for the Performance Factors attained through Industry

Suppliers	Strong Management and Leadership	Resistance to change/Organizational Culture	Employee Trust	Skills and Expertise	Financial capabilities	Effective communication	Performance measure	Education and Training	Customer focus	Planning and Strategy	Thinking development
A	5	4	1	3	3	3	1	2	2	1	2
B	5	4	1	2	1	4	1	2	2	2	1
C	5	4	1	3	1	3	1	1	1	2	1
D	5	4	1	3	2	3	1	1	2	1	2
E	5	4	2	2	3	3	1	2	1	2	1
F	5	3	1	2	2	4	1	2	1	1	2

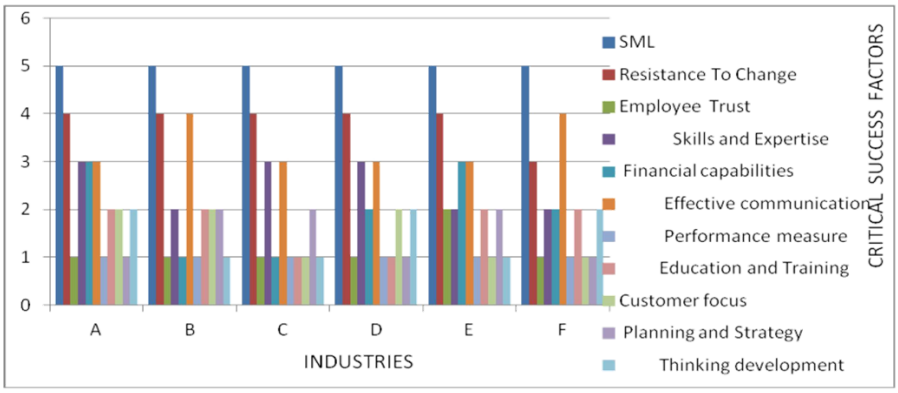

Fig.2. Linguistic Variable Weights for six Suppliers for the Performance Factors Attained through The Industry.

Table 6. Normalized Weights for the Performance Criteria of six Suppliers.

Suppliers	Strong management andleadership	Resistance to change/Organizationalculture	Employee Trust	Skills and Expertise	Financial capabilities	Effective communication	Performance measure	Education and Training	Customer focus	Planning and Strategy	Thinking anddevelopment
A	0.1666	0.1739	0.142	0.3125	0.2500	0.1500	0.1660	0.2000	0.2222	0.1111	.2222
B	0.1666	0.1739	0.142	0.2080	0.0833	0.2000	0.1666	0.2000	0.2222	0.2222	.1111
C	0.1666	0.1739	0.142	0.3125	0.0833	0.1500	0.1666	0.1000	0.1111	0.2222	.2222
D	0.1666	0.1739	0.142	0.3125	0.1666	0.1500	0.1666	0.1000	0.2222	0.1111	.2222
E	0.1666	0.1739	0.285	0.2080	0.2500	0.1500	0.1666	0.2000	0.1111	0.2222	.1111
F	0.1666	0.1304	0.142	0.2080	0.1666	0.2000	0.1666	0.2000	0.1111	0.1111	.1111

3.6.3 Calculation of priority weights of alternative

For each alternate calculate the component and composite are relative to priority, usually the priority weights of each supplier multiplied by weights of the corresponding criterion which is the best global supplier for supply of the parts, thus the given idea is to present the highest score of the supplier as shown in the following Table 7, Table 8, Table 9, Table 10 and the weight, rank values are depicted in Fig. 3(a), Fig. 3(b), Fig. 3(c)

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Table 7. Priority Weights with the Ranking of each Supplier

Suppliers	Alternative Priority Weights	Rank
A	**0.192**	**1**
B	**0.181**	**3**
C	**0.171**	**5**
D	**0.174**	**4**
E	**0.184**	**2**
F	**0.147**	**6**

3.7 Fuzzy Analytical Hierarchy Process implementation

AHP is an intense method to resolve complex verdict problems. Any complex problem can be decayed into a number of sub-problems using AHP in terms of hierarchical levels where each level symbolizes a set of criteria or attributes relative to each sub-problem. However, the pure AHP model has easy way to rank the criteria [4, 5]. To defeat these problems, several researchers incorporate fuzzy theory with AHP to get better the uncertainty.

Then, the research will briefly bring in that how to carry out the fuzzy AHP in the following sections. The form make pair wise evaluation matrices in among all the suppliers similar to AHP but in linguistic terms (not in real numbers) against all the factors. In this research, the linguistic variable and the corresponding fuzzy number considered are shown in the Table 8, 9 and 10.

Table 8.Contrast of the Performance Score of the Variable

Linguistic Variable			Triangular Fuzzy Number
Very strong	Very important	Very high	(8,9,10)
Strong	Important	High	(6,7,8)
Moderate	Moderately important	Medium	(4,5,6)
Weak	Some important	Low	(2,3,4)
Very weak	Less important	Very low	(0,1,2)

Table 9.Alternative and Normalized Weights of Suppliers by AHP among their Ranks

Suppliers	Alternative Priority Weights	Normalized Weights	Rank
A	0.192	1.00	1
B	0.171	0.94	3
C	0.181	0.89	5
D	0.174	0.91	4
E	0.184	0.96	2
F	0.147	0.77	6

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Table 10. Crisp and Normalized Weights of Suppliers by Fuzzy AHP

Suppliers	Crisp Weights	Normalized Weights	Rank
A	182.67	1.00	1
B	162.67	0.89	3
C	130.67	0.79	6
D	158.67	0.83	4
E	164.67	0.90	2
F	148.67	0.81	5

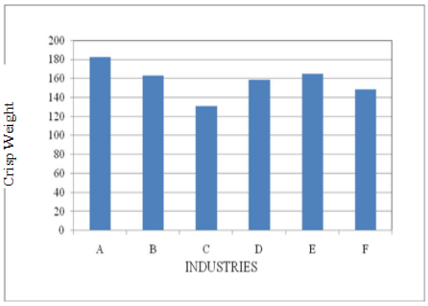

Fig.3 (a)

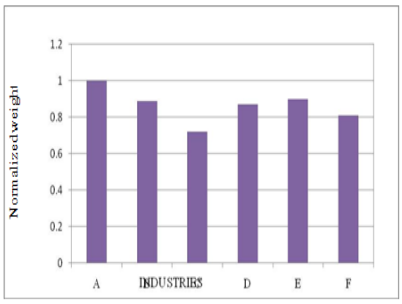

Fig.3 (b)

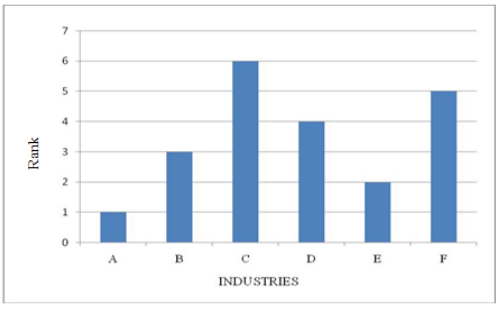

Fig.3 (c)

Fig.3 (a) Crisp Weights of Suppliers by Fuzzy AHP
Fig.3 (b) Normalized Weights of Suppliers by Fuzzy AHP,
Fig.3 (c) Rank of Suppliers by Fuzzy AHP

3.8 RESULTS

The selection of performance factors in the supplier selection process plays a vital role for many small scale industry customers. To break down the connection between them, portions of the central point have been featured and put into an ISM demonstrate. Some valuables are in sighted into the relative importance and the dependence power.

SML, RC, SE, and TE are thought to be the conspicuous variables. From the ISM demonstrate, it is watched that PS, ET, CF and TD are at the base level of the order. PS and EC have their most astounding driving and reliance controls individually. Similarly the AHP technique is also done for those factors with the given six companies and finally the ranking is made to those companies based on their corresponding weights. The AHP results and fuzzy AHP results are shown in Table 11 Figure 4 The ranking is given as follows; COMPANY-A and COMPANY- F has the highest and lowest priority weights.

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Table11. Comparisons of weights of AHP and fuzzy AHP

Suppliers	AHP Rank	FUZZY AHP
A	1.00	1.00
B	0.94	0.89
C	0.89	0.79
D	0.91	0.83
E	0.96	0.90
F	0.77	0.81

A comparison with the weights and rankings to decrease the uncertainly between AHP and fuzzy AHP is performed. Few results are mentioned below. Organization An and B don't give any uncertainty while organization C gives critical changes in the weights bringing about their rankings.

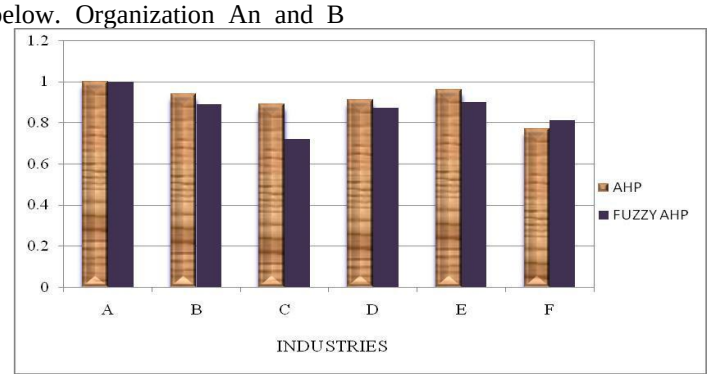

Fig.4 Comparison of weight of AHP and fuzzy AHP

3.9 CONCLUSION

The prime intention of lean manufacturing is to provide superior quality to the customer at an affordable cost and in a way to make certain the customer satisfaction. This concept tends people to be the best techniques like (ISM, AHP) to contribute. Hence, the outcome provided from the techniques (ISM AHP) proves to be of more practical significance. Because of the interaction of criteria with industry experts this practical result proves to be noteworthy. Through the performance factors are found to be only significant in the interaction between the criteria the ISM enhances its use with a perfect inter-relationship. AHP makes it significantly clear with the inclusion of non-quantifiable factors like social, political factors & also some economic factors. These, for mitigating environmental, social factors fuzzy AHP also provides a very useful decision for making loop, hence these integrated approaches may consume less time and consuming these efforts in supplier selection can cause their potential application.

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