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Effective Advanced Manufacturing Technology Implementation In Indian SME: A Fuzzy AHP Approach

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ABSTRACT

The purpose of this paper is to study the enablers for effective Advanced Manufacturing Technology Implementation (AMT) in Indian Small Medium Enterprises (SMEs) by building the awareness of the critical AMT Enablers (AMTEs) and to prioritize AMTEs which, helps in improving the effectiveness of AMT implementation. The AMTEs specific to the Indian SMEs were finalized through a literature review and expert opinion. The present study uses fuzzy analytic hierarchy process (FAHP) methodology to prioritize AMTEs which helps in improving the effectiveness of AMT implementation. In this study, a fuzzy analytic hierarchy process (FAHP) approach has been used for rankings of these AMTEs. This study has attempted to identify the significant and justifiable AMTEs for effective AMT implementation. The findings of this research may be used for developing a confirmation-based ranking of AMTEs.

Keywords- Fuzzy analytical hierarchy method, Advanced manufacturing technology Enabler.

I. INTRODUCTION

In the present era of globalization SMEs should possess the ability to get the organization to innovate quickly and produce an acceptable product and service to capture upcoming business opportunity. Small and medium-scale enterprises (SMEs) are the backbone of the industrialization process of many developed countries and play a crucial role in increasing a country's economy. Advanced manufacturing technology enablers (AMTEs) play important role in successful AMT implementation. Many researchers have discussed the various AMTEs which helps organizations to achieve successful AMT implementation. This study involving the fuzzy set theory with AHP to managerial decision making problem of alternative selection with the developing the framework of incorporating FAHP, to select the best alternative In the Fuzzy AHP, triangular fuzzy numbers are utilized to improve the scaling scheme in the judgment matrices and interval arithmetic is used to solve the fuzzy eigenvector (Cheng and Mon, 1994).

The main objectives of this paper are to identify and rank the AMTEs, to establish relationships among the identified AMTEs using FAHP, and to discuss the organizational implications of this research and suggest directions for future research. In this paper, 35 AMTEs have been chosen on the basis of literature review and the opinions of experts from academia and industry. These AMTEs have been categorized into the five different levels namely strategic AMTEs, organizational AMTEs, technological AMTEs, performance- based AMTEs and human-based AMTEs.

II. CATEGORIZATION OF AMTES

There are many enablers which positively influences the Advanced Manufacturing Technology Implementation. These enablers are known as AMTEs. There are many AMTEs which are widely used in the manufacturing organizations to face market competition and make a stable position of global world. Advanced manufacturing technology Enablers (AMTEs) plays a major role in quality and flexibility improvements in manufacturing organizations. Here, AMTEs have been identified based on review of literature review and the opinions of experts from academia and industry. These AMTEs have been categorized into five perspectives namely strategic AMTEs, organizational AMTEs, technological AMTEs, performance-based AMTEs and human-based AMTEs. These enablers are shown into (Table 1).

Table1 List of main criteria and sub criteria for AMTEs

Major criteria	**Code**	**Sub criterion**
Strategic AMTEs (SE)	SE1	Finance position
	SE2	Government policies
	SE3	Top management commitment
	SE4	Strategic planning
	SE5	Market position
	SE6	Research and development
	SE7	Justification of AMT implementation
Organizational AMTEs (OE)	OE1	Organizational structure/Design
	OE2	Operation strategy
	OE3	Design of work place
	OE4	Capacity utilization
	OE5	Integration of departments
Technological AMTEs (TE)	TE1	Availability of hardware and software
	TE2	Techanical reliability
	TE3	Techanical feasibility
	TE4	

	TE5	Techanical flexibility
	TE6	Technological compatibility
		Maintainability
Performance-based AMTEs (PBE)	PBE1	Shortening product life cycle
	PBE2	
	PBE3	Reduction in lead time
	PBE4	Improvment in product quality
	PBE5	
	PBE6	Improving speed of delivery
	PBE7	
	PBE8	Reduction in product cost
		Reduced processing time
		Reduced changeovers/setup times
		Improved planning and control
Human-based AMTEs (HBE)	HBE1	Organizational culture
	HBE2	Employee relations
	HBE3	Employee motivation
	HBE4	Employee co-operation
	HBE5	Level of skill
	HBE6	Employee training
	HBE7	Team structure, leadership
	HBE8	and education
	HBE9	Integrity of AMT team
		Reward and schemes

The role of strategic AMTEs is very important to achieve the goals of successful implementation of advanced manufacturing technology. It involves the deployment of an organization's capabilities and resources to achieve implementation of AMTEs. These AMTEs help the management of an organization to build a strategy for effective and successful implementation of AMTEs.

The implementation of AMT is affected by a variety of organizational factors. These factors like that organizational structure/organizational design, operation strategy, capacity utilization, design of work place and integration of departments are key members of AMTEs implementation. Organization design involves the mutual adaptation of both the new technology to the organization and organization to the technology. Technological AMTEs are limited to the capabilities of the AMT to improve manufacturing performances.

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Performance Measurement is the survey of companies where measure the performance in the terms of marketing objectives, lead time reduction, competitive advantages and performance improvements while implementing AMT.

Employees play a most vital role in selecting AMT. It may be evident that one of the objectives behind the innovation of AMT is to reduce human intervention. Human factors play a very significant role, especially in many developing countries where AMTs are at the critical early stages of implementation AMT.

III. The Fuzzy AHP Method

The AHP is a flexible multi criteria decision making method which can be used to effectively synthesize the judgments given by a team of experts in order to make better decisions in complex settings, where both tangible and intangible criteria must be considered (Saaty, 1990). It is a powerful decision-making methodology for determining the priorities among different criteria. First, the fuzzy theory is discussed before the development of fuzzy AHP as follows.

The fuzzy AHP method in the decision making process can be applied to many different areas due to its accuracy. The use of fuzzy methodology allows the decision maker to incorporate both qualitative and quantitative data into the decision model.

IV. FUZZY SETS THEORY

A fuzzy set contains elements that have different degrees of membership in it. Fuzzy set theory is suitable for dealing with the uncertainty and imprecision associated with information concerning various parameters. Human decision is generally characterized by vague language, like 'equally important', 'moderately more important', 'strongly more important', 'very strongly more important', and an 'extremely more important'. The fuzzy sets are defined by the membership functions. The fuzzy set theory allows the membership functions to operate over the range of real numbers [0, 1].

A fuzzy number F on R to be a triangular fuzzy number (TFN) if its member ship function is μF (x): R ⟶ [0, 1], and μF (x) is a continuous mapping from R to the [0, 1] is equal to -

$$\begin{vmatrix} 0 & x < a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{c-x}{c-b} & b \le x \le c \\ 0 & c > x \end{vmatrix}$$

If a triangular fuzzy number denoted as F = (a, b, c), where $a \le b \le c$ has the following triangular type membership function as shown in figure 1. The parameters a, b, and c, respectively, indicate the smallest

possible value, the most promising value, and the largest possible value that describe a fuzzy event. In this study triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, have been used to represent subjective pair wise comparisons of major criteria and sub criteria of AMT. This scaling process can then be translated into priority weights (scores) for comparison of alternatives.

Alternatively, by defining the interval of confidence level *α,* the triangular fuzzy number is characterized as:

$0 < \alpha \leq 1$

$\tilde{M}_\alpha = [a^\alpha, c^\alpha] = [(b-c)\ \alpha+a, -(c-b)\ \alpha+c]$

(

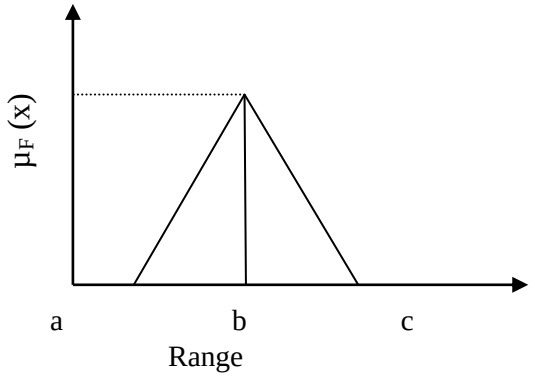

Figure 1 Triangular fuzzy number

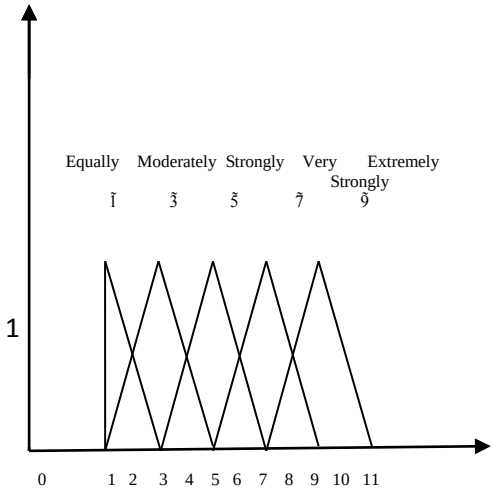

Figure 2 Membership function of triangular fuzzy number

Where a, b, and c are smallest possible value, the most promising value and the largest possible value respectively that describe a fuzzy event. The α-cut values and index of optimism μ incorporated into Fuzzy AHP matrix take care of the accuracy of the measurement. α- cut is known to incorporate the experts or decision makers.

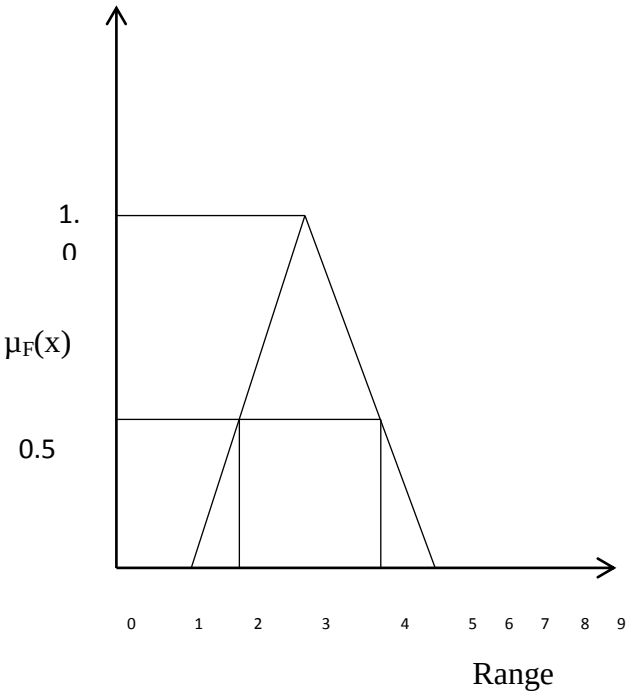

Figure 3 α-cut operations on triangular fuzzy number

Table 2 Definition and membership function of fuzzy numbers

Intensity of importance	Fuzzy number	Definition	Membership function
1	$\tilde{1}$	Equally important/preferred	(1, 1, 3)
3	$\tilde{3}$	Moderately more important/preferred	(1, 3, 5)
5			
7		Very strongly	
9	$\tilde{9}$	important/preferred	(7, 9, 11)

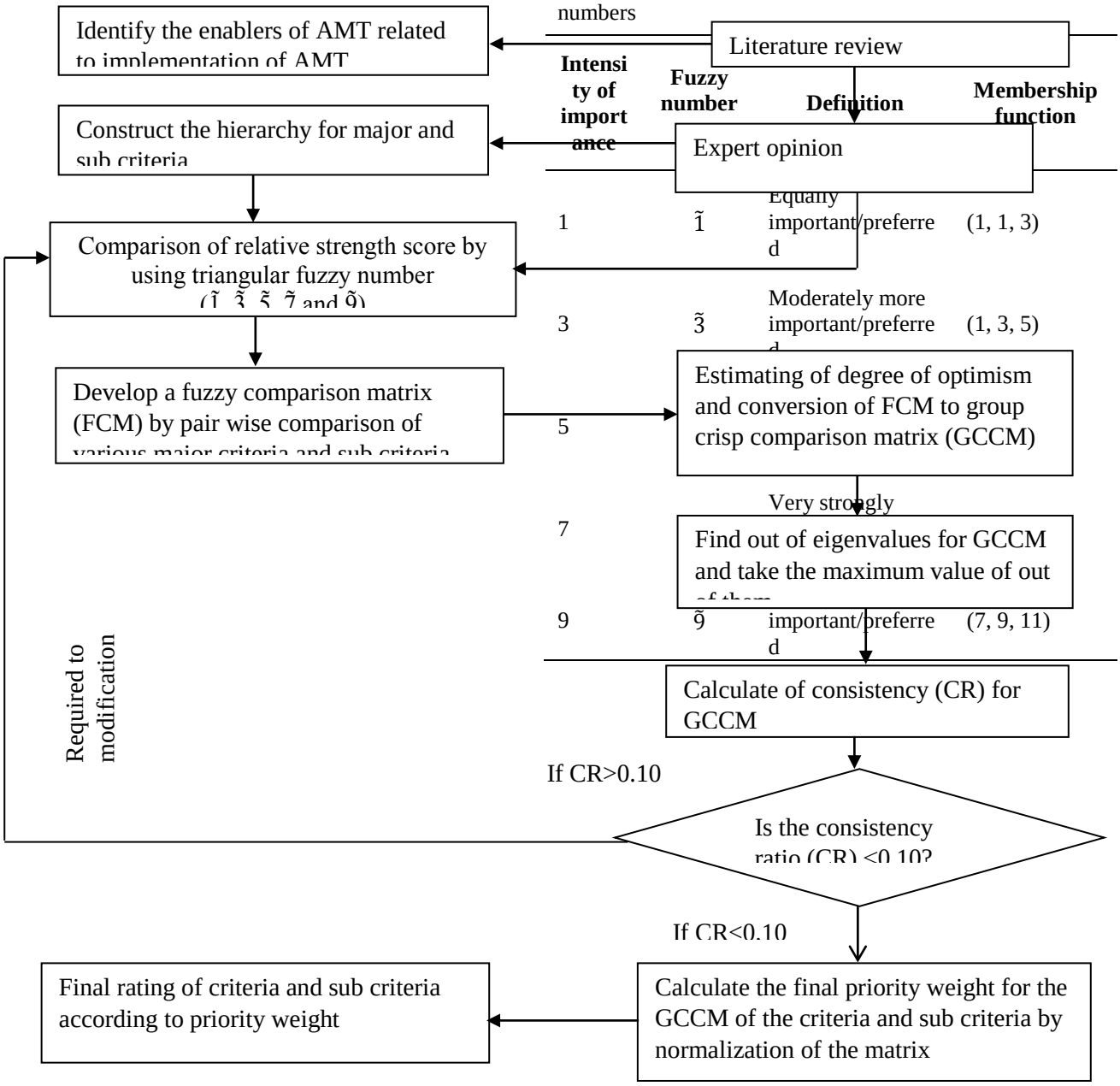

Figure 4 Flow of fuzzy AHP process

V. ANALYSIS AND CALCULATIONS FOR FAHP

Total 35 AMTEs were identified through literature review and discussion with practicing managers as well as researchers. The experts from different fields namely academics (professors and research scholar in the area of AMT) and industries (AMT executives) were asked to give their opinion or judgment over this issue.

(A) Fuzzy Comparison Matrix

In fuzzy comparison matrix major criteria and sub criteria (see Table 1) are compared by using the fuzzy scale which shown in (Table2). Here fuzzy scale used is the five- point scale which shows the participants judgments or preferences among the options which having particular meaning as in the (Table2)

The final fuzzy matrix of major criteria and sub criteria were proposed putting the value 1 in diagonal and other using the average value which is given by expert (Table 3 to Table 8).

Table 3 Fuzzy comparison matrix for the major criteria AMTEs

Attributes	**Strategic**	**organizational**	**Technological**	**Performance –based**	**Human-based**
Strategic	1	$\tilde{3}$	$\tilde{5}$	$\tilde{9}$	$\tilde{7}$
Organizational	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{7}$	$\tilde{5}$
Technological	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{5}$	$\tilde{3}$
Performance-based	$\tilde{9}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	1	$\tilde{3}^{-1}$
Human-based	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	1

Table 4 Fuzzy comparison matrix for sub criteria of Strategic AMTEs

Attributes	**SE1**	**SE2**	**SE3**	**SE4**	**SE5**	**SE6**	**SE7**
SE1	1	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}^{-1}$
SE2	$\tilde{3}^{-1}$	1	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{9}^{-1}$
SE3	$\tilde{5}$	$\tilde{7}$	1	$\tilde{3}$	$\tilde{7}$	$\tilde{9}$	$\tilde{1}^{-1}$
SE4	$\tilde{3}$	$\tilde{5}$	$\tilde{3}^{-1}$	1	$\tilde{5}$	$\tilde{7}$	$\tilde{3}^{-1}$
SE5	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	1	$\tilde{3}$	$\tilde{7}^{-1}$
SE6	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{9}^{-1}$
SE7	$\tilde{5}$	$\tilde{9}$	$\tilde{1}$	$\tilde{3}$	$\tilde{7}$	$\tilde{9}$	1

Table 5 Fuzzy comparison matrix for sub criteria of Organizational AMTEs

Attributes	**OE1**	**OE2**	**OE3**	**OE4**	**OE5**
OE1	1	$\tilde{5}$	$\tilde{7}$	$\tilde{9}$	$\tilde{3}$
OE2	$\tilde{5}^{-1}$	1	$\tilde{3}$	$\tilde{5}$	$\tilde{3}^{-1}$
OE3	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{5}^{-1}$
OE4	$\tilde{9}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{9}^{-1}$
OE5	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{9}$	1

Table 6 Fuzzy comparison matrix for sub criteria of Technological AMTEs

Attributes	**TE1**	**TE2**	**TE3**	**TE4**	**TE5**	**TE6**
TE1	1	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{7}$
TE2	$\tilde{3}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}$
TE3	$\tilde{3}$	$\tilde{5}$	1	$\tilde{7}$	$\tilde{3}$	$\tilde{9}$
TE4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{3}$
TE5	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{3}$	1	$\tilde{5}$
TE6	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	1

Table 7 Fuzzy comparison matrix for sub criteria of Performance-based AMTEs

Attributes	**PBE1**	**PBE2**	**PBE3**	**PBE4**	**PBE5**	**PBE6**	**PBE7**	**PBE8**
PBE1	1	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}$
PBE2	$\tilde{3}$	1	$\tilde{7}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	$\tilde{1}^{-1}$	$\tilde{7}$
PBE3	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}$
PBE4	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	1	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$
PBE5	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{3}$
PBE6	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{5}$	1	$\tilde{3}^{-1}$	$\tilde{7}$
PBE7	$\tilde{5}$	$\tilde{1}$	$\tilde{7}$	$\tilde{5}$	$\tilde{9}$	$\tilde{3}$	1	$\tilde{9}$
PBE8	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{9}^{-1}$	1

Table 8 Fuzzy comparison matrix for sub criteria of Human-based AMTEs

Attributes	**HBE1**	**HBE2**	**HBE3**	**HBE4**	**HBE5**	**HBE6**	**HBE7**	**HBE8**	**HBE9**
HBE1	1	$\tilde{7}$	$\tilde{7}$	$\tilde{9}$	$\tilde{5}$	$\tilde{3}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$
HBE2	$\tilde{7}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$
HBE3	$\tilde{7}^{-1}$	$\tilde{3}$	1	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$
HBE4	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$
HBE5	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	1	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$
HBE6	$\tilde{3}^{-1}$	$\tilde{7}$	$\tilde{5}$	$\tilde{7}$	$\tilde{5}$	1	$\tilde{3}$	$\tilde{3}$	$\tilde{3}^{-1}$
HBE7	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
HBE8	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{3}$	1	$\tilde{3}^{-1}$
HBE9	$\tilde{3}^{-1}$	$\tilde{9}$	$\tilde{7}$	$\tilde{9}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	1

Final Priority of Advanced Manufacturing Technology Enablers (AMTEs) as shown in table 9 as below

Table 9 Final Priority of Advanced Manufacturing Technology Enablers (AMTEs)

Main criteria	**Major criteria weight**	**Sub criteria code**	**CR**	**Ratio weight**	**Final weight**	**Rank**
Strategic (SE)	0.4973196	SE1	0.083	0.087 15298	0.0433 4289	7
		SE2	83	0.059 39441	0.0295 38007	1 0
		SE3		0.292 30162	0.1453 67332	2
		SE4		0.162 46461	0.0807 9684	4
		SE5		0.039 50487	0.0196 46547	1 3
		SE6		0.022 02252	0.0109 52233	1 9
		SE7		0.337 15898	0.1676 75775	1
Organizational (OE)	0.2626944	OE1	0.073 88	0.492 88601	0.1294 78403	3
		OE2		0.133 14125	0.0349 75463	8
		OE3		0.066 96789	0.0175 92091	1 4
		OE4		0.033 34386	0.0087 59245	2 0
		OE5		0.273 66099	0.0718 89214	5
Technological (TE)	0.1359917	TE1	0.082 74	0.245 31216	0.0333 60429	9
		TE2		0.102 58992	0.0139 51382	1 6
		TE3		0.412 41858	0.0560 85523	6
		TE4		0.055 85361	0.0075 9563	2 2
		TE5		0.154 70332	0.0210 38375	1 1
		TE6		0.029 12241	0.0039 60408	2 6
Performance-based (PBE)	0.0353110	PBE1	0.087 76	0.107 55772	0.0037 97972	2 7
		PBE2		0.246 39988	0.0087 00629	2 1
		PBE3		0.035 89499	0.0012 67488	3 4
		PBE4		0.067 29206	0.0023 76151	3 0
		PBE5		0.046 08493	0.0016 27306	3 2
		PBE6		0.158 18811	0.0055 85782	2 4
		PBE7		0.315 87756	0.0111 53957	1 8
		PBE8		0.022 70477	0.0008 01728	3 5
Human-based (HBE)	0.0686831	HBE1	0.088 28	0.291 11522	0.0199 94725	1 2
		HBE2		0.027 67539	0.0019 00834	3 1
		HBE3		0.038 86714	0.0026 69519	2 9
		HBE4		0.018 52962	0.0012 72673	3 3
		HBE5		0.052 91464	0.0036 34347	2 8
		HBE6		0.164 12476	0.0112 72613	1 7
		HBE7		0.077 15104	0.0052 9898	2 5
		HBE8		0.108 85208	0.0074 76309	2 3
		HBE9		0.220 77011	0.0151 63197	1 5

VI. FINAL RESULT AND DISCUSSION

In the study of AMT implementation involves the various enablers which are useful for the predicting the successful implementation of AMT. These enablers are grouped in hierarchy based model to support the successful implementation of AMT.

The criterion weights for five main AMTEs are summarized as: strategic AMTEs (0.4973), organizational AMTEs (0.2626), technological AMTEs (0.1359), performance-based AMTEs (0.0353) and human-based AMTEs (0.0686). These analytic result shows that strategic AMTEs and organizational AMTEs are more important than the other AMTEs. Further this study shows that the effective application of AMT in different area and provides the benefits.

It can be showed that from the (Table 9) that strategic AMTEs having total seven enablers out of them justification of AMT implementation (SE7) is having the highest rank. . Rest of all other AMTEs with final weights are shown in (Table 9) are having the important and provides the different degree. These AMTEs cannot be ignored if AMT needs the successful implementation. The findings of this study can be used for developing an evidence based ranking of AMTEs in AMT implementation.

VII. CONCLUSION

From the study of AMT implementation identifies the total 35 enablers and these enablers are categorized into five groups namely strategic, organizational, technological, performance-based and human-based AMTEs. In among the AMTEs,

justification of AMT implementation and top management commitment and organizational structure are most important AMTEs for successful implementation of AMT. Successful AMT implementation is only possible if management should not be ignore managerial aspects such as organizational culture, employee training and education, integration of departments, better planning and control and employee co-operation. The fuzzy AHP techniques have been used to analyze to the ranking of different AMTEs. Fuzzy AHP is a combination of AHP and fuzzy logic. It is very suitable for evaluating alternatives when qualitative and quantitative observation and preferences are expressed only with linguistic vagueness. This methodology mainly handles vague and ambiguous data and has been used to improve the imprecise ranking of most significant AMTEs.

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