AHP-based expert analysis of Agility in manufacturing system

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Abstract: To achieve the ever growing customer demand and to maximize the revenues with reckless and intense variations in client outlooks, struggle, and technology. Which are generating a gradual unreliable environment. The agility in manufacturing is becoming a key model in MS towards right direction to react with different pressures posed by environmental vagueness. Organizations with good manufacturing practice are pursuing to boost agility in dissimilar direction of manufacturing system. To survive in this extremely unstable environment and to achieve agile manufacturing, organizations need to develop organization capabilities. The main objective of this paper is to apply (AHP) analytical hierarchy process procedure to evaluate agility in manufacturing system.

Keywords: Agility; organization capabilities; AHP analytical hierarchy process; AM (Agile manufacturing), MS (Manufacturing system), Ia (Insourcing system based approach). Mb (Manufacturing support system based approach), Bc (Business excellence system based approach), Rd (Risk mitigation strategy based approach)

1 Introduction

Agile in MS orignated about in late 90s and was announced first placed out in a description enabled in *Manufacturing Enterprise Strategy* (; Hormozi, 2001; Vernadat, 1999). Sangari and Razmi (2015) found from the empirical data (collected from automotive manufacturing companies in Iran) that the agile capabilities partially mediate the relationship between business intelligence competencies. Therefore, agile concept is gaining importance in various sectors but not restricted to manufacturing (Thilak et al., 2015; Fayezi et al., 2015; Liu and Liang, 2015), software (Misra and Singh, 2015; Mandal and Pal, 2015; Stettina and Hörz, 2015), healthcare (Tolf et al., 2015), etc. Advancing the agile manufacturing investigation of manufacturing explanations that was introduced by Gunasekaran and Yusuf (2002), all theories led to the similar-meaning. Agile manufacturing defining are receptiveness most keywords confirm, flexibility (Narasimhan and Das, 1999 Sharifi and Zhang, 1999; Sohal, 1999;) meaning of agility in manufacturing system, with literature further emphasizing on the capability to adjust to vagaries in the professional setting that they referred to as flexibility (Sharifi and Zhang, 1999; Robertson and Jones, 1999). Adding communication technology, information technology develops various development of research about agility (Sharp et al., 1999)

The presentation of (AHP) analytical hierarchy process is extensively described for handling multi-criteria decision-making (MCDM) problems according to (Saaty, 1980). Application of AHP is considered amongst the popular and extensively used decision making methodology in the world today. Saaty (1990), Saaty and Vergas (1982), defines and elaborate on the process Saaty and Kearns (1985). Precise mathematical structure define AHP which is based on the of stable matrices and their associated right eigen vector's capability to produce true or estimated weights, (1994a, 1994b).

Cracking multiple criteria decision making problems, efforts made by decision-makers for breaking the goal for making decision phenomenon into its essential portions, affecting common to the exact outlook. After forming hierarchy, significance of every norm in pair is judge by- decision-makers for comparisons. Scoring the concluding value is on a virtual source, equating the rank of one conclusion different to another.

2 Literature review

2.1 Agile manufacturing literature review

The agility, AM and some significant aspects related to AM (i.e., frameworks, enablers, impediments, results and agility assessments, and benchmarking) reported in the literature are mentioned and discussed in detail.

These days the vibrant business situation, manufacturing sphere is experiencing intense deviations and experiencing vagueness (Zhang, Sharifi, 1999). This environment is increasing acknowledgement for manufacturing skill to adapt in an unexpected situation and respond rapidly in varying markets situation is vital capability for effectiveness (Yusuf et al., 1999), (Bititci et al., 1999; Maskell, Van Assen, 2001). Sharifi and Zhang (2001), concluded that disabling erratic fluctuations, enduring pressures in the turbulent situations, and taking benefit with different modifications which help in making opportunities serious capabilities of agility in MS.

MS investigation to attain agility in manufacturing descriptions was concluded by various authors like Gunasekaran and Yusuf (2002), their outcomes indicate that various models studied led to same meaning. Various keywords commonly used in MS defining are awareness and flexibility (Perry et al., 1999; Sharifi and Zhang, 1999. Describing manufacturing agility, few authors enhanced the significance on the capability for adjusting to various variations in the business environment that they referred to as adaptability (Sharifi and Zhang, 1999). Information technology and communication technology were another important finding of research about agility in MS (Sharifi and Zhang, 1999; Sharp et al., 1999). Agility in manufacturing have massive literature. Effort was made for learning more papers that review the agility in MS literature till 2015. Gunasekaran (1999) converse the situations of agile manufacturing that just deal with enablers to improve the agility in manufacturing systems. Workforce characteristic was defined which is primary factor in the agile manufacturing progress. (Sherehiy et al. 2007), concluded from the literature survey of agility in MS, that manufacturing flexibility is extremely dependent on workforce reasonably than technology side. Agility defines the quickness and authority of reaction in the face of inside and outside measures of organization (Taleghani et al., 2014). Flexibility and agility has increased ambiguity between the terms. If we consider that flexibility is subset or precursor of agility, then there is barely any differences but when treating them solely (Routroy et al.,2015; Thilak et al., 2015) and at tactical and business network level, it must be flexible at process level for an organization to become agile (Ali et al., 2014; Thilak et al., 2015).

Taleghani et al. (2014) explored the issues touching the organizational agility in a Sugar Company in Iran and they found significant factors and positive relationship them (i.e., speed, responsiveness, flexibility, competence, empowerment and job security) and agility of organizations with the employees. The connection between entrepreneurial coordination and agility was examined in manufacturing organizations using statistical analysis taking inputs from 100 manufacturing firms of Kerman Province by Nejad et al. (2014). Constructive and significant relationship was confirmed between entrepreneurial positioning and agility. To continuously enhance their agility the agility in manufacturing organizations is the need of the time and effort should put on it.

Liu and Liang (2015) considered high-tech manufacturing industries for attaining Justifiable reasonable benefit and settled that it can be attained by continuously enhancing resource allocation aligning with resource-based operations tactic sustained by the sense and respond hint of agile strategy applications. Agility in MS is one of the significant antecedents for a manufacturing organization to become agile and also to have an effective and efficient agile supply chain. In the following sections, a literature review on AM is carried out to give a clear insight about them.

2.2 An overview of AHP

(Saaty, 1990) problem for complex decision- making glitches associated to tactical development of organizational resources are solved using AHP with validation of advance and latest manufacturing technology (Albayrakoglu, 1996). Applications of AHP has been used widely in finance, marketing, education, public policy, economics, medicine, and sports (Saaty, 1994a, 1994b). Different formats of AHP is applied in a multiple set-ups like the designing of tool for large-scale systems or composite ratio scales (Weiss and Rao, 1987). AHP method has been used to regulate area significances with unbiased function weights in a goal LP origination (Gass, 1986).

AHP was implemented in an automobile manufacturing plant for implementation of agility in MS Bayazit (2005). Further settled that employing FMS is the best substitute. (Lee and Yang 1997), offered AHP decision idea for the organizations looking for a location to develop different facility, either repositioning of a surviving capability. Application of AHP conclusion proves that the suggested AHP idea can offer outline to support decision creators in investigating various location, assessing site for location replacements and which will make final location collections. Further (Ordoobadi 2010) applied AHP and Taguchi loss method to develop a decision exemplary to help decision makers with selection of the suitable provider for the outsourcing commitments. Integrated analytical approach was developed, merging “quality function deployment” (QFD) and “analytic hierarchy process” (AHP) method, for enhancing the efficiency of sourcing conclusions (Ho et al. (2011). QFD and AHP method were collective used to improve to quantity the performance of different suppliers. (Costa and Evangelista 2008) suggested with AHP technique with demonstrating its competence with the dimension of various value of brand intangible resources addition to its capacity to overwhelm the defects already existing procedures.

3 AHP for validation of agility in manufacturing system.

Results provided by AHP are very much improved as compared to other counting methodologies meanwhile the standards weights or main concern recognized from the AHP ever exist on random measures, proper percentage measure of human interference is used (Golden et al., 1989), AHP use very simple procedure in three different stages which was concluded by (Saaty, 1980), like intelligence phase, design phase and Choice phase, which have been briefly explained in Table 1.

Table 1 Different AHP phases

	"Intelligence phase"
Primary problem is discussed to attain :	Well established, consensual view of the Problematic situation
"Design phase"	
Key description of options is Discussed:	Find a reviewed description of varieties; Acquire an initial set of goals/measures.
Initial set of intentions were Discussed :	Achieve a reviewed set of goals/measures.
"Choice phase"	
AHP models were structured in one or more:	Attain expert choice ideas Following with verdicts.

Source: Saaty (1980)

3.1 configuration of model and description preparation of hierarchy

Important aspects for credentials needs a systematic examination of the problem. On behalf of existing study, attributes range has been resolute through literature survey. Different elements recognized with their explanation. Table 2.

Table 2 description of various Attributes into consideration

Attribute	*Abbreviation*
Technological capabilities	**TIC**
In-house R&D	**IRDC**
Manufacturing informatics	**MI**
Risk management capabilities	**RMC**
Manufacturing performance	**MP**

Market flexibility	**MF**
Product customization	**PC**
Smart manufacturing	**SM**
Supply chain management	**SCM**

3.2 Analytic Hierarchy Process Modeling

Analytic Hierarchy Process (AHP) has been discussed in detail. The dimensions of agility in MS have been identified from literature review. For the purpose of combined comparison method of AHP, three respondents compared each objective with each other, freely. These were: technology manager of Tata Motors, Jamshedpur, the researcher himself. Values of these matrices as filled by the respondents were taken into consideration. Generated matrices explain the various intention of Eigen vector and weights for the various purposes.

Equally important	**Weakly more important**	**Strongly more important**	**Very strongly more important**	**Absolutely more Important**
1	3	5	7	9

Calculation of weights and Eigen vector of these matrices also show the goals. Various weightings formulated from respondents seems too reliable with consistency ratio was found to be well within the limit of 10%.

Various respondents' weights is given in Table 6.1.

Table 3.1 Weights of various agilities manufacturing system

**Respondent Objective **	**Researcher**	**Sourcing Manager**	**Technology Manager**
MF	**0.380**	**0.080**	**0.068**
MP	**0.178**	**0.277**	**0.081**
PC	**0.221**	**0.040**	**0.068**
SM	**0.091**	**0.086**	**0.264**
SCM	**0.129**	**0.517**	**0.519**

Supply chain management (SCM) role has been found to be the mostly significant, trailed by manufacturing flexibility (MF), manufacturing performance (MP), smart manufacturing (SM) and product customization (PC). This could be attributed to the fact that the organizations these days are more focused to the deliverance of new or customized products quickly and flexibly for achieving competitive excellence in the vibrant business environment. Fast obsolesces of the existing technology and competitor strategies have also influenced the organizations to shift their focus towards agility in manufacturing system.

The relative weight scored by smart manufacturing is less than other four types of agilities i.e. manufacturing performance, manufacturing flexibility, product customization and supply chain management. The reason can be recognized to the fact that these days the organizations easily restructure their existing processes quickly to the varying customer demands. Additionally, the role of supplier involvement at different level can be managed with ease.

4 Fuzzy Set Theory

Subsequently defining the weights of the goals, the following action has been taken to make position matrices. Qualitative value of support in these matrices for every profile or course of action to each objective has to be decided. Again, the three respondents have done this exercise. Position matrices beside with the weights resolute before are presumed from the position matrices, outcome of these weighted position matrices are demonstrated. Exclusively for all matrix it has done by respondent. The weight of the objective as resolute previously has been increased by value of each position of the position matrix and weighted values have been attained.

It can be concluded from various optimistic, weighted position matrices, pessimistic weighted position matrices and average by using Fuzzy Set Theory. Maximum worth of each position is designated for optimistic matrix, for pessimistic the bottom outputs and for attaining a average matrix, selection of average values has done.

Table 4.1 Weighted position matrix (optimistic)

**Profile Objectives **	***Ia***	***Mb***	***Bc***	***Rd***
MF	**0.114**	**0.342**	**0.266**	**0.190**
MP	**0.160**	**0.249**	**0.194**	**0.138**
PC	**0.111**	**0.155**	**0.199**	**0.066**
SM	**0.132**	**0.185**	**0.132**	**0.079**
SCM	**0.156**	**0.260**	**0.467**	**0.362**

Table 4.2 weighted position matrix (Pessimistic)

**Profile Objectives **	***Ia***	***Mb***	***Bc***	***Rd***
MF	**0.048**	**0.056**	**0.034**	**0.020**
MP	**0.040**	**0.056**	**0.040**	**0.024**
PC	**0.036**	**0.028**	**0.012**	**0.020**
SM	**0.026**	**0.077**	**0.060**	**0.043**
SCM	**0.064**	**0.039**	**0.090**	**0.116**

Table 4.3 Average weighted position matrix

Profile Objectives	*Ia*	*Mb*	*Bc*	*Rd*
MF	**0.078**	**0.153**	**0.114**	**0.089**
MP	**0.094**	**0.143**	**0.108**	**0.072**
PC	**0.069**	**0.077**	**0.082**	**0.036**
SM	**0.062**	**0.115**	**0.086**	**0.056**
SCM	**0.125**	**0.186**	**0.341**	**0.246**

Established on above pessimistic, optimistic and average weighted position matrices, further matrices output is Calculated at several percentages of optimism (80%, 60%, 40% and 20%) and formulated.

Conclusion of weighted position matrices for optimism, pessimistic, average and different cautious approaches have been collected and describes the proportional association among altered agilities with several outlines. Which further displays the classification of changed approaches following under different market conditions.

Table 4.4 Preferred strategies under cautious optimism for achieving agility in manufacturing system

Objective	**100 %**	**80 %**	**60 %**	**40 %**	**20 %**	**Pessimistic**	**Average**
MF	**Mb-Bc-Rd-Ia**	**Mb-Bc-Rd-Ia**	**Mb-Bc-Rd-Ia**	**Mb-Bc-Rd-Ia**	**Mb-Bc-Ia-Rd**	**Mb-Ia-Bc-Rd**	**Mb-Bc-Rd-Ia**
MP	**Mb-Bc-Ia - Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Ia-Rd**	**Mb-(Ia,Bc)-Rd**	**Mb-Bc-Ia-Rd**
PC	**Bc-Mb-Ia-Rd**	**Bc-Mb-Ia-Rd**	**Bc-Mb-Ia-Rd**	**Bc-Mb-Ia-Rd**	**Mb-Ia-Bc-Rd**	**Ia-Mb-Rd-Bc**	**Bc-Mb-Ia-Rd**
SM	**Mb-(Ia,Mb)-Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Ia-Rd**	**Mb-Bc-Rd-Ia**	**Mb-Bc-Rd-Ia**	**Mb-Bc-Ia-Rd**
SCM	**Bc-Rd-Mb-Ia**	**Bc-Rd-Mb-Ia**	**Bc-Rd-Mb-Ia**	**Bc-Rd-Mb-Ia**	**Bc-Rd-Mb-Ia**	**Bc-Ia-Mb-Rd**	**Bc-Rd-Mb-Ia**

(Ia- Insourcing innovation system based approach; Mb- Manufacturing support system based approach; Bc - Business excellence system based approach; Rd - Risk mitigation strategy based approach)

Different conclusion from the Hadley's matrix of cautious optimism are concluded from the above table

• Mb undertakings in manufacturing and Bc in manufacturing technology has profoundly motivated the fulfilment of agility in large and medium scale MS in most of the optimism conditions.

• Mb and Bc inclined the success of manufacturing performance in most of the matrices situations carefully monitored by contribution of Ia in handling minor product and process dissimilarities demands. Further, the Bc and Mb in manufacturing technology has reasonably inclined the success of product customization in pessimistic conditions. Also, Business excellence and manufacturing support system approach impact smart manufacturing with slight contribution of insourcing innovation. Business excellence and risk mitigation strategy approach influenced the supply chain management

From following results dominance matrices are arranged. These matrices concluded that, each course of action dominance of over the others has been formulated. Cell signifies that the readings of course of action governs other courses of achievement in different conditions and it is dominated by another course of action in how many criteria. Profile are written on the top in the matrix, dominates the profile written on the left. Thus, row sum shows the number by which a criterion is dominated and the column sum depicts the number by which the profile dominates all other profiles. The matrices are presented in Table 4.5 to Table 4.6.

Table 4.5 Dominance matrix - optimistic

Profile	***Ia***	***Mb***	***Bc***	***Rd***
Ia	-	5	4	2
Mb	0	-	2	1
sBc	0	3	-	0
Rd	3	4	5	-
Colum sum	3	12	11	3
RANK	III	I	II	III

In the optimism dominance matrix, 'manufacturing support based approach' has emerged as the preferred strategy for achieving agility in manufacturing system. Further, 'business excellence system', based approach' have occupied the second position, followed by Insourcing innovation system and Rd in the third position

Table 4.6 Dominance matrix - pessimistic

Profile	***Ia***	***Mb***	***Bc***	***Rd***
Ia	-	**3**	**3**	**2**
Mb	**2**	-	**1**	**1**
Bc	**3**	**4**	-	**2**
Rd	**3**	**4**	**3**	-
Colum sum	**8**	**11**	**7**	**5**
RANK	**II**	**I**	**III**	**IV**

The result of pessimistic matrix depicts the significant importance of manufacturing support system and insourcing innovation system based approach technology for achieving agility in manufacturing system.

Table 4.7 Dominance matrix - average

Profile	Ia	Mb	Bc	Rd
Ia	-	5	5	2
Mb	0	-	2	1
Bc	0	3	-	0
Rd	3	4	3	-
Colum sum	3	12	10	3
RANK	III	I	II	III

In average dominance matrix, 'manufacturing support based approach', 'business excellence based approach', 'risk mitigation strategy' and 'Ia' have emerged as the preferred strategies at different altitudes that appears to be a emerging approach in the large scale Indian manufacturing organizations. The similar dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled. The results of Hadley's dominance matrix of cautious optimism are also in line with the optimistic and the average matrix. The results of all the dominance matrices have been summarized in Table 4.7

Table 4.7 Hadley's matrix of cautious optimism

Rank Profile	100%	80%	60%	40%	20%	Pessimistic	Average
Ia	3	3	3	3	4	2	3
Mb	1	1	1	1	1	1	1
Bc	2	1	2	1	2	3	2
Rd	3	3	3	3	3	4	3

The results indicate that manufacturing based approach has affirmed as the most preferred strategy whereas insourcing innovation based approach and Rd has occupied the last (third) position for managing the agile MS under all degrees of optimism. Business excellence based approach have engaged second rank under various degrees of optimism. The dominance matrix for a high degree of optimism 80%, 100% seems to be the most realistic strategy. Various matrices concluded that manufacturing support based approach has performed widely chosen approach; whereas Bc showed second rank, further insourcing innovation system based approach, Rd collectively have come into consideration as the preferred approaches ranked as number three and four separately.

Results and Discussion

The results of qualitative modeling depicted that all the approaches employed like optimistic, average, pessimistic and Hadley's cautious optimism have brought out the manufacturing support based approach as the most preferred strategy for achieving agility in Indian manufacturing organizations followed by business excellence based approach

Following observations have also been depicted from the results of qualitative analysis:

a. For succeeding manufacturing flexibility, manufacturing support has emerged as the most proffered approach followed by business excellence based approach.
b. For achieving manufacturing performance, manufacturing support has emerged as the most proffered approach followed by business excellence based approach.
c. In case of product customization, business excellence based approach is most important.
d. Role of manufacturing based approach is significant for following smart manufacturing monitored by insourcing innovation system based approach.
e. Finally, for achieving supply chain management, risk mitigation based approaches have been found to be equally important.

In this analysis a shared FST and AHP approach application is studied to regulate the dissimilar approaches for achieving agility in manufacturing system, below vibrant market conditions. Conclusions have been drawn using Hadley's matrix of cautious optimism as detailed in Table 6.9. Mb and business excellence based approach have considerably inclined the success of agility in most of the situations. Further it can be concluded that qualified to the fact that under competitive market conditions, it is desirable to adopt new manufacturing technology to keep pace with the vigorous environment. The organizations must invest in advanced technologies.

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