Agility Evaluation and Identification of Agile Obstacles by Exploring Fuzzy Degree of Similarity (DOS) Concept

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ABSTRACT

Agility metrics are difficult to define, mainly due to the multidimensionality and vagueness of the concept of agility. In this paper, a fuzzy logic, knowledge-based framework has been presented for the assessment of an enterprise's agility; in an Indian perspective. The necessary expertise explored to quantitatively determine and evaluate overall agility degree has been represented via fuzzy expert systems. Apart from estimating overall agility appraisement index; the study has been extended to identify agile barriers (obstacles towards achieving agility). The proposed appraisement module has been implemented in an Indian enterprise as a case study. Data obtained thereof, has been critically analyzed to reveal the current scenario of existing agile practices of the said enterprise and to seek for ill-performing areas which need future improvement.

Keywords: Agility metrics, agility appraisement index, fuzzy logic

1. INTRODUCTION

Agility is the ability of an organization to adapt to change and also to seize opportunities that become available due to change. While there has been much work and discussion of what agility is and how firms can become agile there is little work at measuring the agility of a firm (Arteta and Giachetti, 2004). Agility assessment is indeed necessary for the strategic planning of determining how much agility the organization is currently pursuing, determining the extent that is required, and then for assessing the gap and formulating a strategy for closing any perceived weaknesses (drawbacks).

The customers' dynamic demands and the ever increasing intensity of global competition force the practitioners to adopt agile principles. The *twenty-criterion* agile model as proposed by (Ramesh and Devadasan, 2007) and its implications procedure would enable the organizations to focus towards attaining agility. Radfar et al. (2011) presented a model for evaluating the agility in supply chain of two dominant telecommunication companies in *Iran*. To avoid any ambiguities which were caused by linguistic methods, in this evaluation model Fuzzy Inference System (FIS) was proposed. Tseng and Lin (2011) suggested a new agility development method for dealing with the interface and alignment issues among the agility drivers, capabilities and providers using the Quality Function Deployment (QFD) relationship matrix and fuzzy logic. A fuzzy agility index (FAI) for an enterprise composed of agility capability ratings and a total relation-weight with agility drivers was developed to measure the agility level of an enterprise.

Agility metric is difficult to achieve due to existence of imprecise-incomplete information in relation to agile capabilities/attributes as well as criterions. Effort has been made by previous researchers to assess agility extent of enterprises, their supply chains (Shahrabi, 2011; Yauch, 2011). Lin et al. (2006) developed a fuzzy agility index (FAI) based on agility providers using fuzzy logic. The FAI comprises attribute' ratings and corresponding weights, and was aggregated by a fuzzy weighted average. To illustrate the efficacy of the method, this study also evaluated the supply chain agility of a *Taiwanese* company.

Literature reveals that attempts have been made by pioneer researchers towards assessing agility. However, due to existence of imprecise incomplete evaluation information; it seems difficult to measure an overall numeric score to represent the agility degree. Therefore, it requires subjective judgment collected from a highly experienced decision-making group to facilitate such an approximate estimation.

Managerial decision-making process often experience uncertain-vague data which is really difficult to analyze. Fuzzy logic has the capability to overcome such imprecise linguistic human judgment. In this paper an effort has been made to establish a scientific mathematical background to assess overall agility degree for a given organization and to assess the extent of successful performance of the key elements that stimulate organizational agility. The fuzzy based agility evaluation model presented here can be effectively implemented in industries supply chain to attain competitive advantage in the market.

2. PROCEDURAL HIERARCHY

A fuzzy based performance appraisement module in agile manufacturing proposed in this paper has been present below. General hierarchy criteria (GHC) for evaluating overall organizational agility degree, adapted in this paper has been shown in Table 1. It consists of two-level index system; which aims at achieving the target to evaluate overall appraisement index. 1^{st} level lists out a number of agile capabilities/ enablers; 2^{nd} level comprises of various agile attributes. Procedural steps for agility evaluation have been presented as follows:

1. Selection of linguistic variables towards assigning priority weights (of individual agile capabilities as well as attributes) and appropriateness rating (performance extent) corresponding to each 2^{nd} level agile attributes.

2. Collection of expert opinion from a selected decision-making group (subjective judgment) in order to express the priority weight as well as appropriate rating against each of the evaluation indices.

3. Representing decision-makers' linguistic judgments using appropriate fuzzy numbers set.

4. Use of fuzzy operational rules (Zadeh, 1965; 1975; Kaufmann and Gupta, 1991) towards estimating aggregated weight as well as aggregated rating (pulled opinion of the decision-makers) for each of the selection criterion.

5. Calculation of computed performance rating of 1^{st} level agile capabilities and finally overall agility performance index called Fuzzy Performance Index (FPI).

Appropriateness rating for each of the 1^{st} level capability U_i (rating of i_{th} agile capability) has been computed as follows:

$$U_i = \frac{\sum U_{ij} \otimes w_{ij}}{\sum w_{ij}} \tag{1}$$

In this expression (Eq. 1) U_{ij} is denoted as the aggregated fuzzy appropriateness rating against j_{th} agile attribute (at 2^{nd} level) which is under i_{th} main criterion in the 1^{st} level. w_{ij} is the aggregated fuzzy weight against j_{th} agile attribute (at 2^{nd} level) which is under i_{th} main criterion in 1^{st} level.

The *Fuzzy Performance Index (FPI)* has been computed as:

$$U(FPI) = \frac{\sum U_i \otimes w_i}{\sum w_i} \tag{2}$$

In this expression (Eq. 2) U_i is denoted as the computed fuzzy appropriateness rating (obtained using Eq. 1) against i_{th} agile capability at 1^{st} level. w_i is the aggregated fuzzy priority weight against i_{th} agile capability in 1^{st} level.

6. Investigation for identifying ill-performing areas those seek for future improvement.

3. CASE STUDY

The course towards conducting a cross-sectional study, which has been aimed at exploring the role various agile practices in Indian industries; the proposed appraisement module has been implemented in a famous railway wagon part manufacturing Industry at eastern part of India. In the primary stage, after extensive literature review and periodic discussions with the industries top management, an integrated hierarchy model towards agility assessment has been constructed and made for ready to implement. The model encompasses of various agile capabilities as well as agile attributes. An evaluation team consisting of five experts has been deployed to assign priority weights (importance extent) against different agile capabilities as well as agile attributes considered in the proposed appraisement model. A questionnaire has been formed and circulated among the decision-makers (experts) to provide the required detail. The decision-makers have been the employees of the said enterprise. During data gathering it has been assured that the data would be strictly used for academic purpose only. Therefore, experts were requested to provide personal opinion (without any biasness) based on their experience. The outcome of this survey might be of enormous help for the industries in improving productivity as well as profitability.

Collected data has been explored to investigate application feasibility of the proposed appraisement platform. After critical investigation and scrutiny each decision-maker has been instructed to explore the linguistic scale (Table 2) towards assignment of priority weight and appropriateness rating against each evaluation indices. The subjective judgment of the evaluation team members expressed through linguistic terms in relation to weight assignment against various agile capabilities as well as attributes has been obtained next. Appropriateness rating (subjective score as given by the 20 decision-makers) for 2nd level agile attributes has been collected. These linguistic expressions (human judgment) have been converted into appropriate generalized triangular fuzzy numbers as presented in Table 2. The method of *simple average* has been used to obtain aggregated priority weights of 2nd level agile attributes, as well as 1st level agile capabilities. Similarly aggregated fuzzy appropriateness rating has been obtained for 2nd level attributes and then 1st level agile capabilities. Finally, Eq. 2 has been used to obtain overall FPI. T
he FPI thus obtained as: ***U*****= (0.0909, 0.5081, 2.20839)**
The FPI may be compared with a predefined performance estimation scale set by the management to check the current performance practices for the suppliers'. Thus, ill-performing areas have been sorted out and in future said enterprise should think of feasible means towards improvement of overall agility degree.
The concept of '*Fuzzy Degree of Similarity*' has been proposed here to indentify ill-performing areas of agile performance. 2nd level agile attributes have been ranked based on their individual *Fuzzy Performance Importance Index* (FPII) [10]. It has been computed as follows:

$$FPII_j = \lfloor (1,1,1) - w_{ij} \rfloor \otimes U_{ij} \tag{3}$$

Here $FPII_j$ is denoted as the *Fuzzy Performance Importance Index* of j_{th} agile attribute; whose aggregated performance rating is U_{ij} and aggregated priority weight w_{ij}.

From the data set containing FPII values of individual attributes at 2nd level; an ideal FPII $(FPII_{Ideal})$ has been found out. The degree of similarity (DOS) between $(FPII_{Ideal})$ and individual FPIIs (of different attributes at 2nd level) has thus been computed. An attribute which corresponds to highest degree of similarity is assumed to contribute maximum to the overall performance extent. Based on computed DOS values, (Chen, 1996; Hsieh and Chen, 1999; Chen and Chen, 2003; Yong et al., 2004) individual sub-criterions have been ranked (Table 3) and also ill-performing sub-indices have been identified accordingly. Thus, agile attributes have been ranked thus improvement opportunities have been identified.

4. CONCLUSION

In the foregoing study a fuzzy-based performance appraisement module has been proposed and implemented in a real case study to evaluate extent of successful performances of current agile practices of the said industry. Apart from estimating an overall agility degree, the study has been illustrated to identify possibilities as well as necessities for future improvement towards identifying ill-performing agile criterions. 'Agility' as a whole, is a concept of introducing speediness, responsiveness into the existing system, associated supply chain. Achieving 'agility', an industry can gain competitive advantage in the global market. It is indeed difficult to assess agility quantitatively since most of the agile capabilities-attributes as well as criterions are subjective in nature; incompleteness, imprecision and vagueness arises in the decision-making process. In order to tackle such types of inconsistency; fuzzy expert system has been proposed here to deal with decision-makers' subjective judgment towards performance estimation of various agile indices. The proposed decision-support model has been found fruitful in aggregating performance of multiple agile indices into an equivalent single performance appropriateness index. The industries may adopt such an appraisement policy to examine the present agility level, identify ill-performing areas (agile barriers) and seek for feasible means towards overcoming existing agile barriers.

5. REFERENCES

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Table 1. *The Proposed Agility Appraisement Model (3-Level Index System Hierarchy)*

Goal	1st level agile capabilities/enablers, C_i	2nd level agile attributes, C_{ij}
Agility Index, C	Organization management agility, C_1	Agility in institutional framework, C_{11}
		Team building agility, C_{12}
		Production organizing agility, C_{13}
	Product design agility, C_2	Product design flexibility, C_{21}
		Customer demand information agility, C_{22}
		Product design speed, C_{23}
	Processing manufacture agility, C_3	Re-configurability of manufacturing system, C_{31}
		Speed of manufacturing, C_{32}
		Manufacturing flexibility, C_{33}
	Partnership formation capability, C_4	Inter-organization coordination, C_{41}
		Cross collaboration, C_{42}
	Integration of information system, C_5	Information management agility, C_{51}
		Speed of information, C_{52}

Table 2. *Linguistic Scale towards Estimating Priority Weight and Assignment of Performance Rating*

VH	H	M	L	VL
Very High (VH)	High (H)	Middle (M)	Low (L)	Very Low (VL)
(0.75, 1, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0, 0.25, 0.5)	(0, 0, 0.25)

Table 3. *Ranking of Agile Attributes Based on the Concept of ‘Fuzzy Degree of Similarity’*

2nd level attributes, C_{ij}	DOS (Chen, 1996)	Ranking Order	DOS (Hsieh and Chen, 1999)	Ranking Order	DOS (Chen and Chen, 2003)	Ranking Order	DOS (Yong et al., 2004)	Ranking Order
C_{11}	0.8881	13	0.8633	12	0.7556	13	0.3036	13
C_{12}	0.9203	9	0.8964	8	0.8225	9	0.4682	9
C_{13}	0.9303	7	0.9043	6	0.8439	7	0.5267	7
C_{21}	0.9438	4	0.9222	3	0.8730	4	0.6064	4
C_{22}	0.9142	10	0.8840	9	0.8097	10	0.4486	10
C_{23}	0.9267	8	0.8965	7	0.8362	8	0.5138	8
C_{31}	0.9539	2	0.9337	2	0.8953	2	0.6693	2
C_{32}	1.0000	1	1.0000	1	1.0000	1	1.0000	1
C_{33}	0.9466	3	0.9195	4	0.8791	3	0.6227	3
C_{41}	0.9333	6	0.9067	5	0.8503	6	0.5443	6
C_{42}	0.8931	12	0.8660	11	0.7659	12	0.3362	12
C_{51}	0.9072	11	0.8779	10	0.7949	11	0.4103	11
C_{52}	0.9414	5	0.9195	4	0.8679	5	0.5921	5