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Technical paper

Design of agile supply chain assessment model and its case study in an Indian automotive components manufacturing organization

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ABSTRACT

Agile Manufacturing (AM) paradigm is fast instilled in modern organizations. AM enables an organization to evolve products and services quickly and economically in response to the customers' dynamic demands. The effectiveness of AM is largely determined by the performance of Agile Supply Chains (ASC). In order to assess their performance, an ASC assessment model was reported in this research paper. This model is encompassed with agile supply chain attributes whose performance levels need to be determined for assessing the overall ASC performance of the organization. The computation was performed using fuzzy logic approach. The working of this model was examined by conducting a case study in an Indian automotive components manufacturing organization. The experience gained by conducting this case study favored the use of a computerized system which will ensure accuracy of computations involving fuzzy logic.

1. Introduction

Over the past two decades, the global market witnesses the entry of several players to offer products and services to the customers. This situation has been facilitating the customers to demand varieties of products and services [1]. In order to thrive amidst this situation, modern companies have been spontaneously creating a paradigm by which new varieties of products and services are offered to the customers quickly in response to the dynamic demands of customers'. The issues connected with this paradigm are today addressed by the researchers under the terminology Agile Manufacturing [2]. In the meantime, it is to be noted that modern companies are forced to create broader market niche by selling their products and services to the customers who are geographically dispersed. In order to meet this situation, organizations have been creating supply chains to distribute their products and services to their customers. As supply chains become larger and thickly networked, managing them poses several challenges. Researchers and practitioners have been deliberating the solutions to face these challenges under the field 'Supply Chain Management' (SCM). A product or service developed by an organization quickly to face the customers' dynamic demand will fail to serve the purpose of the supply chains if they do not facilitate their distribution to the right customers. In other words, supply chains too are required to possess agile characteristics. On realizing this situation a relatively new discipline 'ASC' is fast emerging during the recent times [3]. An ASC is a dynamic alliance of member companies, the formation of which is likely to need to change frequently in response to fast-changing markets [4]. Lou et al. [3] have defined ASC as a network with the topological structure which is composed of autonomous or semi-autonomous enterprises. All enterprises work together for procurement, production and delivery. An important factor to achieve agility in manufacturing enterprises is flexibility among firms so that they can react to changes effectively, driven by customer designed products and production capacity to rapid new product launch. Eshlaghy et al. [5] have proposed supply chain agility model and discussed its constructs. They have defined 'supply chain agility' as a measure of the ability to efficiently adapt to a rapidly changing global competitive environment to provide products and services. They have hypothesized that supply chain agility is determined by four flexibility components namely product development flexibility, sourcing flexibility, manufacturing flexibility, and logistics flexibility. Each flexibility is composed of two dimensions namely range and adaptability. They have also found out that an organization's Information Technology (IT) flexibility and global competitive environment influence its level of supply chain agility. To study the effects of supply chain agility on performance, two additional constructs called supply chain performance and competitive performance have been included in this model. As mentioned earlier, some researchers have contributed their focus toward identification of characteristics of ASC. For example, Van Hoek et al. [6] have stated that

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Nomenclature

R_j	average fuzzy ratings
R_{ji}	fuzzy performance ratings
W_{ji}	performance weights
W_j	average performance weights
FPII_j	FPII for jth attribute
W'_j	complement of jth attribute's importance weight
$D(\text{FASCI}, \text{AL}_i)$	Euclidean distance between FASCI and AL_i
AL	agility level
AL_i	corresponding Fuzzy number for natural-language expression
FPII_{ijk}	FPII for ijkth attribute
$f_{\text{FASCI}}(x)$	triangular fuzzy number of FASCI
$f_{\text{AL}_i}(x)$	triangular fuzzy number of AL_i

marketing/customer sensitivity, cooperative relationships, process integration, and information integration are the attributes of ASC. Iskanius [7] enumerated virtual enterprise/organization, outsourcing, collaborative relationships, production planning, product design and service, customer focus, customer and market sensitivity as the characteristics of ASC. In this study, the case network was undergoing a shift toward paper-oriented business, where quick response was the priority and agility was recognized as the facilitating factor. Using a constructive approach, an ASC for a steel product network was developed. In this study, qualitative methods such as interviews, observations, questionnaires and documents were used as data collection methods. Chopra et al. [8] explained aspects related to inventory management, supplier relationship management, enterprise wide relationship management, supply chain partner selection and internal SCM as the characteristics of ASC. Paneerselvam [9] mentioned that time management and nature of management are the characteristics of ASC. Few researchers working on ASC have been deliberating useful hints [5]. Yet the success of these researches will be ensured only if a model is offered to researching and practicing communities to measure the agility level of supply chains. However this task has to be tactfully handled as assessment of agility in supply chains is largely dependent on the experts' estimation of ASC activities [10]. This estimation is largely available in the form of linguistic expressions like 'very good' and 'satisfactory'. These linguistic expressions are so vague that converting them into numerical values may prove to be difficult. Not only that, ensuring consistency and reliability of these numerical values also impose a challenge. The field of Artificial Intelligence offers a solution to face these challenges by offering 'fuzzy logic' methodology. Hence, it is a prudent proposition to incorporate fuzzy logic methodology into the model for assessing agility level of supply chains. On realizing the need of such a model, the research reported in this paper was carried out. This research was begun by studying the literature on assessment of ASC. This study resulted in the identification of ASC enablers and their supporting criteria and attributes. This study also revealed that few researchers have contributed ASC assessment models. Subsequently an ASC assessment model incorporated with five agile enablers, 20 criteria and 86 attributes were discussed. These drivers of ASC were derived from the earlier researches reported in the literature. The framework of this model facilitates the surmounting of deploying fuzzy logic methodology. This methodology facilitates the assessment of agility in the supply chain network of the organization. After designing this model, a case study was carried out in an automotive manufacturing company situated in India. Since the management of the company does not prefer to reveal its identity, this company is designated in the remaining part of the paper as 'XYZ'. The steps involved in using the fuzzy logic supported ASC assessment model developed during this research are elaborately presented while describing this case study.

2. Literature review

An overview of literature indicated that a considerable number of researchers have deliberated about the meaning and characteristics of ASC management.

2.1. Assessment models in AM, fuzzy logic applications in AM and SCM arenas

Few researchers have developed models for measuring agility index. They have deliberated the methods for measuring agility index by computing and combining the intensity levels of agility enabled-attributes. Other decision making methods were developed by Ren et al. [11] based on the logical concept of Analytic Hierarchical Process (AHP). Yang and Li [12] have proposed a procedure to assess agility using fuzzy logic approach for mass customized product manufacturing. They have identified the ranges in a scale of 2–10 to indicate whether the company is agile or not. Yu et al. [13] used fuzzy multi-objective vendor selection program for lean procurement based on cost minimization, delivery schedule violation minimization, and maximizing the quality level of the purchased quantity. They developed a solution algorithm using fuzzy AHP. But performance measurement and identification of drag factors and improvement proposals may be difficult with the method. Using the numerical problem, they proved fuzzy logic approach is suitable for vendor selection problem. Lin et al. [10] have developed a fuzzy logic based assessment methodology for agility evaluation. The evaluation procedure includes identifying agility capabilities, selecting linguistic variables sets and interpreting the values of the fuzzy rating and fuzzy weights integration, fuzzy index labeling, and defuzzification. The authors have mentioned the need for computerization of assessment. In order to overcome the vagueness of the agility assessment and to include the human knowledge, Tsourveloudis and Valavanis [14] proposed IF – THEN rules for measuring enterprise agility based on fuzzy logic. The disadvantage of this approach is its inflexibility since IF– THEN rules must be redesigned to fit the new situation as it involves several levels of linguistic terms or different membership functions usage. IF – THEN method based assessment requires a prior mathematical knowledge to convert IF-THEN rules into mathematical model. The industrial experts find difficult while solving the complex mathematical equations. Jain et al. [15] developed a new approach based on Fuzzy Association Rules Mining to support the decision makers by enhancing flexibility in making decisions for evaluating agility with both tangible and intangible attributes/criteria such as flexibility, profitability, quality, innovativeness, proactivity, speed of response, cost and robustness. The model could still take into account other advanced features of agile system characteristics. Ganguly et al. [16] proposed three techniques and associated metrics for determining enterprise agility. They presented a case study involving Apple's digital media to demonstrate the utility of methodology and associated metrics. Lin et al. [10] utilized fuzzy logic approach for assessing supply chain agility of manufacturing organization. They mentioned that a supply chain must possess a number of distinguishing attributes such as distribution networks, manufacturing capabilities, interchange-ability of personnel and learning organization [17]. Due to qualitative and ambiguous attributes linked to agility assessment, most measures are described subjectively using linguistic terms, and cannot be handled effectively using conventional assessment approaches. Fuzzy logic provides an effective means