A review on applying Fuzzy Logic inference system in Improving Agility Assessment of Supply Chain

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***Abstract*- Fuzzy logic is logic based approximate reasoning and can be expressed linguistically to capture the inherent vagueness of human mind; thus, it can be applied to the areas which involve human decision making like supervision, monitoring, planning, scheduling etc. Fuzzy logic has got various applications in various fields and it has got most of the value in field of Engineering and Medical with all the application. This paper deals with various application related to agile supply chain. Most of the appropriate paper have been reviewed which is directly or indirectly linked with agile supply chain. Some of the literature papers have been found which is very much suitable to improve agility assessment level with few criteria and various attributes. Nowadays in turbulent and violate global market places, agility has been viewed as a fundamental key strategic consideration of a supply chain needed for survival. To achieve the competitive edge, industries must align with suppliers as well as their customers to streamline operations. Agile Supply Chain (ASC) is considered as a dominant competitive advantage. However, so far a little effort has been made for designing, operating and evaluating agile supply chain in recent years. To this end, the present work attempts to develop a procedural hierarchy towards estimating an overall performance metric for an agile supply chain. Therefore in this paper various application of fuzzy logic has been discussed and come up with an attainment level of improving the agility assessment.**

***Index Terms*- Agile Supply Chain, Fuzzy logic, Fuzzification, Fuzzy Inference system and Linguistic Variable.**

I. INTRODUCTION TO AGILE SUPPLY CHAIN

Agility refers to the capability of an organization to respond quickly in accordance with the dynamic demands of the customers. Supply chain management (SCM) is a business function which basically aims at organizing and synchronizing monitoring the use of the various resources distributed across the supply chain in order to optimize its response to customer orders and shareholders expectations for profitability Yee Ming Chen [14]. Supply Chain Agility is an operational strategy focused on inducing velocity and flexibility in the supply chain. All organizations have supply chains of varying degrees, depending upon the size of the organization and the type of product manufactured. These networks obtain supplies and components, change these materials into finished products and then distribute them to the customer. Included in this supply chain process are customer orders, order processing, inventory, scheduling, transportation, storage, and customer service. A necessity in coordinating all these activities is the information service network. Agility is a concept that incorporates the ideas of flexibility, balance, adaptability, and coordination under one umbrella. In a business context, agility typically refers to the ability of an organization to rapidly adapt to market and environmental changes in productive and cost-effective ways. Business agility is the ability of a business to adapt rapidly and cost efficiently in response to changes in the business environment. Business agility can be maintained by maintaining and adapting goods and services to meet customer demands, adjusting to the changes in a business environment and taking advantage of human resources. The agile enterprise is an extension of this concept, referring to an organization that utilizes key principles of complex adaptive systems and complexity science to achieve. Santosh Kumar Sahu et al. [3].

The difference between supply chain management and supply chain agility is the extent of capability that the organization possesses. Key to the success of an agile supply chain is the speed and flexibility with which these activities can be accomplished and the realization that customer needs and customer satisfaction are the very reasons for the network. Customer satisfaction is paramount. Achieving this capability requires all physical and logical events within the supply chain to be enacted swiftly,

accurately, and effectively. The faster parts, information, and decisions flow through an organization, the faster it can respond to customer needs.

Kumar V. et al [6] developed a conceptual framework for implementing and managing supply chain flexibility in supply chain organizations. Jassbi J. et al. [7] developed an approach based on Adaptive Neuro Fuzzy Inference System (ANFIS) for evaluating agility in supply chain considering agility capabilities such as Flexibility, Competency, Cost, Responsiveness and Quickness. Yaghoubi Nour Mohammad et al. [8] Highlighted the concept, importance and necessity of accessing agility with the Goldman methodology based on fuzzy approach. Garbie I.H. [9] proposed a conceptual model to measure the agility level of the petroleum companies based on existing technologies, level of qualifying human resources, production strategies, and organization management systems. Radfar R. et al. [10] presented a model for evaluating the agility in supply chain of two dominant telecommunication companies in Iran. To avoid any ambiguities which are caused by linguistic methods, in this evaluation model we have used Fuzzy Inference System (FIS) which is neither stochastic nor random. Tseng et al. [11] suggested an agility development method for dealing with the interface and alignment issues among the agility drivers, capabilities and providers using the QFD relationship matrix and fuzzy logic. Vinod et al. [12] attempted to assess the agility of the manufacturing organization using a 30-criteria agility assessment model which could be utilized to measure agility and to identify the agile characteristics of organization.

Literature reveals that considerable amount of work has been carried out by pioneer researchers towards agile system modeling followed by agility appraisement module in Agile Supply Chain Management (ASCM). In general it can be see that a lot of research has been done about agility, despites their differences in detail, all unanimously introduce agile organization as a dynamic, location oriented, flexibility and growth oriented organization which is focused on identification of business environment changes and speed in to give appropriate response to them.

Therefore we can categorize the important aspects of agile supply chain into four groups of “enriching the customer”, “cooperation”, “organizing to master change and uncertainty” and “leveraging the impact of people and information”. The elements of agile supply chain are shown in below block diagram Y.Y. Yusuf et al. [15].

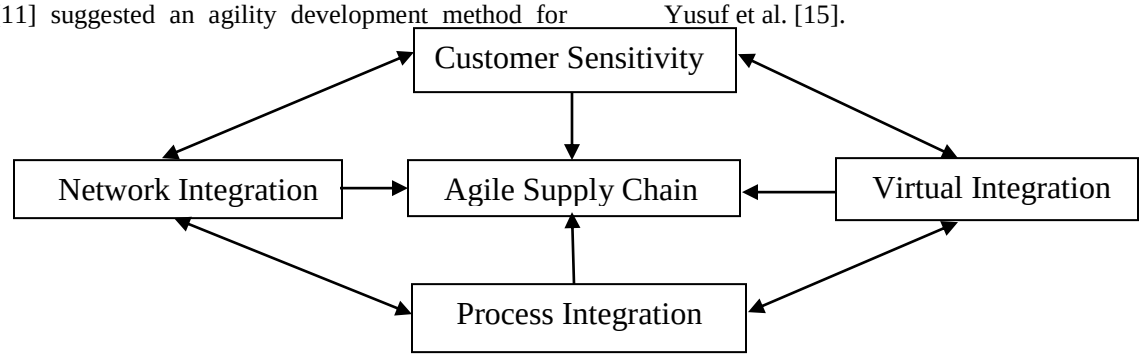

Fig. 1. Elements of Agile Supply Chain

II. Attainment Of Agility Assessment Level

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 customer’s dynamic demands and the ever increasing intensity of global competition force the practitioners to adopt agile principles. Nedhish Somanath et al [2]. The main aim of agility is to achieve organizational flexibility to satisfy the employees and its regular customers. The qualities which makes an industry agile includes responsiveness towards uncertain changes, competitive in achieving desired goal, adaptive towards different goals with same facilities and ability to carry out the task in short time period.

Supply Chain Agility Assessment has been considered as one of the most important issues in world class manufacturing research study. The environmental issue as well as speed, variety, flexibility and integration in production line come along with customer relationship and mass customization concept should come to light in today's research study. Therefore, due to ambiguity of agility assessment, we have constructed a fuzzy rule based system, considering agility capabilities such as Responsiveness, competency, flexibility and Quickness to evaluate agility in supply chains. This evaluation helps managers to perform gap analysis between existent agility level and the desired one, Deepak Kumar et al [1].

The twenty-criterion agile model as proposed by Ramesh and Devadasan and its implications procedure would enable the organizations to focus towards attaining agility S. Devadasan et al [5]. 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. 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.

To be truly agile a supply chain must possess a number of distinguishing characteristics. Firstly, the agile supply chain is market sensitive. By market sensitive is meant that the supply chain is capable of reading and responding to real demand. Most organizations are forecast-driven rather than demand-driven. In other words because they have little direct feed-forward from the market place by way of data on actual customer requirements they are forced to make forecasts based upon past sales or shipments and convert these forecasts into inventory. Secondly, the agile supply chain is process integration. By process integration is meant collaborative working between buyers and suppliers, joint product development, common systems and shared information. This form of co-operation in the supply chain is becoming ever more prevalent as companies focus on managing their core competencies and outsource all other activities. In this new world a greater reliance on suppliers and alliance partners becomes inevitable and, hence, a new style of relationship is essential. Finally, the agile supply chain is network based. There is a growing recognition that individual businesses no longer compete as stand-alone entities but rather as supply chains. We are now entering the era of network competition where the prizes will go to those organizations who can better structure, co-ordinate and manage the relationships with their partners in a network committed to better, closer and more agile relationships with their final customers. It can be argued that in today's challenging global markets, the route to sustainable advantage lies in being able to leverage the respective strengths and competencies of network partners to achieve greater responsiveness to market needs. Therefore the conceptual model for assessing the supply chain is as shown below in block diagram Y.Y. Yusuf et al. [15]**.**

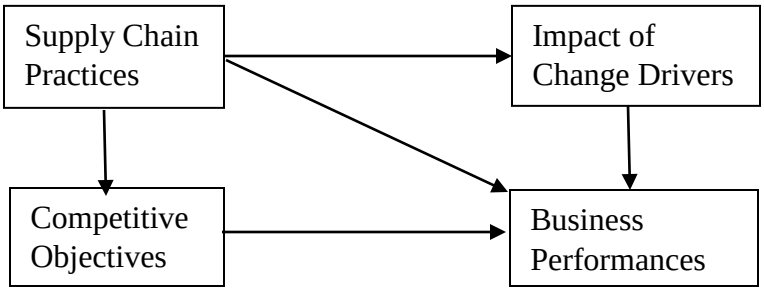

Fig. 2. Conceptual model for assessing the Supply Chain

III. FUZZY LOGIC

Fuzzy logic has become an important tool for number of different applications ranging from the control of engineering system to artificial intelligence. Practical applications of fuzzy logic pose a unique set of problems. The design of systems, which apply fuzzy logic to make use of human knowledge and experience, is a daunting task without facing engineering problems of real world systems. Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership Deepak Kumar et al. [1]. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values), fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. When linguistic variables are used, these degrees may be managed by specific functions. Fuzzy logics provide the basis for logical systems dealing with vagueness, e.g. for formalizing common natural language predicates such as “tall” or “fast”. Design choices in this framework are made as to which real numbers to take as truth values, and which properties connectives should have. In fact logics based on real numbers occur in a number of areas in logic. Fuzzy logic is based on the theory of fuzzy sets, which a generalization of the classical is set theory. Saying that the theory of fuzzy sets is a generalization of theclassical set theory means that the latter is a special case of fuzzy sets theory. To make a metaphor in set theory speaking, the classical set theory is a subset of the theory of fuzzy sets.

A fuzzy set is a set without a crisp, not clearly defined boundary. It can contain elements with a partial degree of membership with multi-valued logic. Fuzzification comprises the process of transforming discrete values into grades of membership (continuous) for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. Defuzzify evaluate several membership sets established by the system designer for a fuzzy logic based control system, such as "speed too fast," "speed too slow" and "speed about right" at a specific input value. Degree of membership is a specific value that defines how each point in the input space is mapped to the specific environment being studied lying between 0 and 1. Linguistic Variable means relating to language, (plain language words and statements). While variables in mathematics usually take numerical values, in fuzzy logic, the non-numeric linguistic variables are often used to facilitate the expression of rules and facts. Rahul Patidar, Dr. Nagendra Sohani [4].

IV. ROLE OF FUZZY LOGIC RELATED TO AGILE SUPPLY CHAIN

Fuzzy logic has contributed in vast way in analysis of agility. With help of fuzzy logic it is easy to evaluate the agility of any system. Fuzzy logic provides a useful tool to deal with problems in which the attributes and phenomena are imprecise and vague. Furthermore, fuzzy logic has found large application in management decisions. Manufacturing systems engineering lacks analytic and closed-form mathematical solutions in the simplest possible cases. Since manufacturing systems are operated and managed by people, it is necessary to record and utilize human knowledge and perceptions about agility and its factors (parameter, quantification and measurement). However, due to the imprecise and vague definition of agility indicators, and when a situation is characterized by either lack of evidence or the inability of the experts to make a significant assessment of an event, linguistic expressions are used to estimate ambiguous events. Most agility measurement are described subjectively by linguistic terms, which are characterized by ambiguity and multi-possibility. Thus, the scoring of the above techniques can always be criticized, because the scale used to score the agility capabilities has two limitations: 1) Such techniques do not take into account the ambiguity and multi-possibility associated with the mapping of one’s judgment to a number, and 2) The subjective judgment and the selection and preference of evaluators have a significant influence on those methods. However, fuzzy logic provides a useful tool to deal with problems in which the phenomena are imprecise and vague. Using fuzzy concepts, evaluators can use

linguistic terms to assess the indicators in a natural language expression and each linguistic term can be associated with a membership function. Fuzzy logic by making no global assumption about the independence, exhaustiveness, or exclusiveness of facilitated evidence, tolerates a blurred boundary in definitions. This brings hope of incorporating qualitative indicators into decision-making since it is often vaguely de-fined or has unclear boundaries.

Also with help of fuzzy inference system agility of supply chain can be evaluated. Fuzzy inference (reasoning) is the actual process of mapping from a given input to an output using fuzzy logic. The process involves: membership functions, fuzzy logic operators, and if-then rules. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision which is described below with block diagram. Because of its multi-disciplinary nature, the fuzzy inference system is known by a number of names, such as fuzzy-rule-based system, fuzzy expert system, fuzzy model, fuzzy associative memory, fuzzy logic controller, and simply fuzzy system.

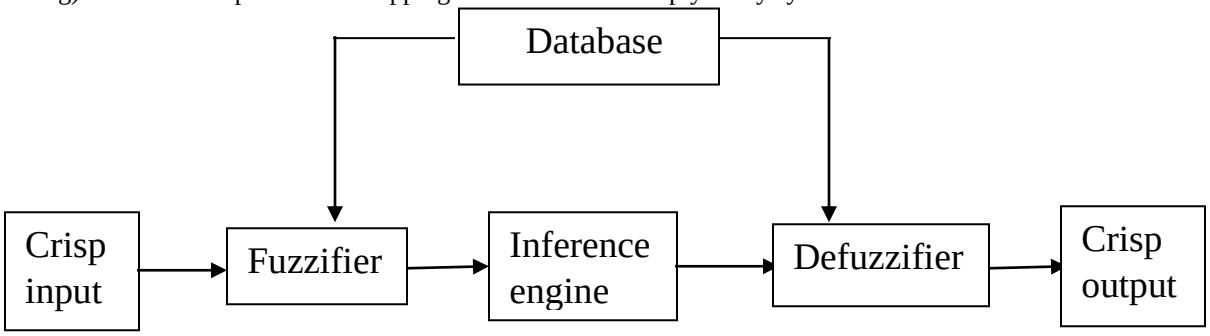

Fig. 3. FUZZY INFERENCE SYSTEM

Fuzzy logic has wide variety of application in industrial sector. Some of the examples are:

Example 4.1. Mitsubishi manufactures a fuzzy air conditioner. While conventional air conditioners use on/off controllers that work and stop working based on a range of temperatures, the Mitsubishi machine takes advantage of fuzzy rules; the machine operates smoother as a result. The machine becomes mistreated by sudden changes of state, more consistent room temperatures are achieved, and less energy is consumed. These were first released in 1989. P. Ponce-Cruz and F.D. Ramirez-Figueroa [13].

Example 4.2. Fisher, Sanyo, Panasonic, and Canon make fuzzy video cameras.These have a digital image stabilizer to remove hand jitter, and the video camera can determine the best focus and lightning. Fuzzy decision making is used to control these actions. The present image is compared with the previous frame in memory, stationary objects are detected, and its shift coordinates are computed. This shift is subtracted from the image to compensate for the hand jitter. P. Ponce-Cruz and F.D. Ramirez-Figueroa [13].

Example 4.3. Fujitec and Toshiba have a fuzzy scheme that evaluates the passenger traffic and the elevator variables to determine car announcement and stopping time.This helps reduce the waiting time and improves the efficiency and reliability of the systems. The patent for this type of system was issued in 1998 P. Ponce-Cruz and F.D. Ramirez-Figueroa [13].

Example 4.4. The automotive industry has also taken advantage of the theory. Nissan has had an anti-lock braking system since 1997 that senses wheel speed, road conditions, and driving pattern, and the fuzzy ABS determines the braking action, with skid control P. Ponce-Cruz and F.D. Ramirez-Figueroa [13].

Example 4.5. Since 1988 Hitachi has turned over the control of the Sendai subway system to a fuzzy system. It has reduced the judgment on errors in acceleration and braking by 70%. The Ministry of International Trade and Industry estimates that in 1992 Japan produced about $2 million worth of fuzzy products. U.S. and European companies still lag far

behind. The market of products is enormous, ranging from fuzzy toasters to fuzzy golf diagnostic systems, P. Ponce-Cruz and F.D. Ramirez-Figueroa [13].

V. FUTURE SCOPE OF PAPER

As we have discussed in the paper how fuzzy logic has improved the agility of various supply chain to the great extent which increases the supply chain profitability, this paper has wide range of scope in future industries environment. Fuzzy inference system which has been used in this paper to show the evaluation of agility of any supply chain can be used in future industry problems on agility.

Also we know that the real world is complex; this complexity generally arises from uncertainty. Humans have unconsciously been able to address complex, ambiguous, and uncertain problems thanks to the gift of thinking. This thought process is possible because humans do not need the complete description of the problem since they have the capacity to reason approximately. With the advent of computers and their increase in computation power, engineers and scientists are more and more interested in the creation of methods and techniques that will allow computers to reason with uncertainty. Thus to handle this type of complexity in future this paper will be helpful for reference.

And also organizational performance measurement & metrics have received more attention by researchers. Performance measurement & metrics play important role to setting objective, evaluating performance & determining future course of action.

VI. LIMITATION OF PAPER

The method of fuzzy inference system used in evaluating agility of supply chain cannot be applicable to every organization. In this paper most of the literature have been referred which is related to manufacturing organization rather than service or automobile industries. Hence the paper is limited to manufacturing industries only. Limitation will be eliminated in further research and it has been discuss in importance of paper.

This method require highly trained employee as the method require good analytical skill and high thinking power. Also method is little bit complex to understood and require graphical and tabular way for its best representation.

VII. IMPORTANCE OF PAPER

As we know today agility is the most important attribute to be consider for any organization to have its competitive position in the market, this paper has clearly discuss about importance of agility and its evaluation process. Agility of any supply chain in an organization has to be periodically evaluated so as to improve the overall performance of organization. In this paper fuzzy logic inference system has been used to evaluate agility which has efficiently and effectively improve the supply chain agility. Organization needs to meet the customer demand in time and for this they had to be truly agile in nature and the agility can be achieved with the help of fuzzy logic. Also we know that the increasing competition has been forcing the manufacturing organizations to develop various manufacturing paradigms for satisfying the requirements of the customers. The demand conditions of market are fluctuating due to varied customer's requirement. This situation has marked the emergence of a new manufacturing paradigm called Agile manufacturing (AM). AM enables an organization to produce a variety of products within a short period of time in a cost effective manner. Therefore it is necessary to evaluate the agility which increase the supply chain efficiency of an organization.One of the biggest challenges facing organisations today is the need to respond to ever increasing levels of volatility in demand. For a variety of reasons product and technology life-cycles are shortening, competitive pressures force more frequent product changes and consumers demand greater variety than ever before.

To meet this challenge the organisation needs to focus its efforts upon achieving greater agility such that it can respond in shorter time-frames both in terms of volume change andvariety change. In other words it needs to be able quickly to adjust output to match market demand and to switch rapidly from one variant to another. To a truly agile business volatility of demand is not a problem; its processes and organisational structure as well as its supply chain relationships enable it to cope with whatever demands are placed upon it.

VIII. CONCLUSION AND DISCUSSION

This study has addressed the questions of how to measure and improve supply chain agility. Agile paradigm has become an important avenue in recent

times. Many organizations around the world have been attempting to implement agile concepts in their supply chain. The agility metric is an important indicator in agile performance measure.Agile manufacturing is the contemporary manufacturing strategy which enables the modern organization to survive in the competitive environment. The evaluation of supply chain agility gains vital importance in modern scenario. Agility in nature is associated with complexity and ambiguity; therefore conventional evaluations are inappropriate and incompetent. However fuzzy logic is a very powerful tool to compensate this limitation and deal with vague and complex situations. Agility of any supply chain can be effectively evaluated using fuzzy inference system. Exploration of fuzzy logic helps in dealing with decision-makers' linguistic evaluation information efficiently, thereby eliminating ambiguity, imprecision and vagueness arising from subjective human judgment. Also for any industries to be survive in today competitive market they had to be truly agile and should periodically evaluate their supply chain agility. Agile supply chain result in improving the response and service to the customer, therefore increasing the supply chain profitability. Agility of any supply chain has to be evaluated to improve its overall performance.

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