Fuzzy DEMATEL approach for agile supplier selection performance criteria

Mukesh Kumar1, Dixit Garg1, and Ashish Agarwal2
1Mechanical Engineering Department, NIT Kurukshetra, Kurukshetra
2Mechanical Engineering Department, IGNOU, New Delhi
mk10@nitkkr.ac.in

Abstract. The strategy of agile supplier selection (ASS) process has adopted the recent era due to global competitive edges in a rapidly changing business environment. The sustainable agile performance criteria are the key necessity for market variations and more customer responsiveness. Therefore, the adaptation of ASS process is a key requirement to overcome the market variations and influence by number’s criteria. ASS is a major issue in Supply Chain Management (SCM), due to various uncertainties of market demand, lumpy demand, mismatch of supply and demand patterns, in these causes' selection of supplier procedure is a difficult task in the automotive industry. Due to volatile market demand and more customer responsiveness, it is stimulating that inter-organization to balances the effective and efficient customer needs in volatile market demand patterns. This problem will be resolved by incorporating with human judgment skill capability in linguistic scale patterns. ASS has employed such method as the Fuzzy logic and DEMATEL approaches to perform better in global competitiveness. It strives to sustain the volatile market demand by appropriate ASS performance criteria. With the help of the literature survey, 14 agile supplier selection criteria have selected for better influence or support for ASS procedures.

Keywords: Agile supplier selection, Fuzzy DEMATEL, Agile supply chain,

1. Introduction
The agile supply chains concept has popular in recent business environment to perform better in volatile market and continuous changing customer demands. In agile supply chain (ASC), the alignment of the inter-organization and competitive factors are a key requirement which leads to effective improvement of the operations as well as technology tools to achieve the agility of entire supply chains. The different ASC issues in supplier selection process it becomes more crucial to survive in recent competitive and global business environment. Therefore, agile supplier selection process as most appealing issue in successful operations of ASC, an effective supply partner selection becomes essential process may enhance effectiveness, efficiency, quality, safety and profit. The adoption of agile manufacturing approach has essential for sustain the firms in complex supply network and fluctuation of market demand. The agile supplier should be required to effective cooperative and supporting teams which is force multiplier of firms to deliver product effectively and economical. Firms have focused on new setup up arrangements, agility requires in supply chains, and speedily taken decision in complex network and diverse aspects. Agile supplier selection can
The adaptation of ASS then firms can develop a capability to respond the customer demand effectively and more competitive to enhance the performance such as production ratio, reconfigure of the products design and downstream effective match of the customer requirement. Agile Supply Chain (ASC) system has adopted for cost effective and quick response in uncertain demand, variety of product demands, and also products match for the customer satisfaction [1]. The most of researchers’ notices that firms can be strengthen their agility by capitalizing on their supplier’s agile capability through the long term, collaborative relationship [2]. Manisra Baramichai notices that SC agility has adopted by firms of following reasons (i) Agile supplier selections has motivated to strong integration within the SC members, (ii) The appropriate integration of supplier-buyer relationship and sufficient necessity of internal infrastructure as well as closer relationship to enhance the capability of suppliers resources utilization (iii) The firm has sufficient resilience to adopt change in SC structures and quick responds on the changes market variations [3]. Philip Thomas identified that total elapsed time between the customer query and customer needs being fundamental drivers’ elements to achieving business performance [4]. The contribution of business metric and effective ranking procedure of Business Systems Engineering (BSE) schemes have significant expected reduction of the total cycle time in ASC, the fruitful time compression is key enablers [5]. Agrawal investigates that ASC has inherently focused on the market demand and also it can be capable to synchronized the supply and demand responses [6]. The synchronization can be achieved through tighter and close integration across the firms internal functions such as suppliers and supplies and customers and customer’s customer satisfaction [7] & [8]. Agrawal has examined that consider of expert’s opinion to construct an Interpretive structure modelling tool its help to complete the process high level of quality characteristics identified in ASCs [9]. The employment of IT tools which helps to centralized and collaborative planning approach as well as streamlines process integration. It overcomes of uncertainty situation, resistance to change develop, and trust factor enhancement. In the recent extant researcher has focused on changing business environment of ASC, better perform in more dynamics and unexpected market situation [10]. The ASC is a key necessity to change in rapid business environment where high flexibility and quick reconfigure are requirement based on market demand. ASC has proposed a dynamic network of companies’ members which constituents are change frequently adapted. The successful operation of ASC can be depends upon the firm’s ability to select the most appropriate potential partners in certain situations. The agile supplier selection is a key role play to consistently increase importance in uncertain demand and complex scenario [11] & [12]. Büyüközkân identified that supplier performance has decides based on formulation of the environmental performance criteria. An integrated fuzzy decision making methods has taken initiatives to assessment of green supplier attributes. The FAHP techniques was used to identify the relative weights of the evaluation criteria and decision oriented as well as fuzzy group decisions making method was decided to green suppliers priority [13]. Huang and Hu investigate that develop systematic procedures for supplier selection criteria in automotive industry. The adopted methodology provides two stages of supplier selections, first stage using FANP approach integrate with GP model to select the best supplier and decide optimal order quantity. Second stage of supplier selection has based on DNP approach to overcome the resource constraint and minimise total procurement expenses [14]. Halder indentified that the assessment of quantitative approach has essential for strategic supplier selection procedure under fuzzy environment in a disaster scenario. Agile Supply chain management is better reinforcement strategy to effective supplier selection procedure. Prior practices of supplier selection based on criteria such as cost, quality and performance related, but very less consider of agility related criteria. Indeed, agile supplier selection process and partners selection is major obstacles in agile supply chain. Literature review of agile supplier selection has identified the very limited scope in agile supply chain [15]. Supplier selection is fundamental issues in the SCM, where overall assessment of the supply chain performance can base on the appropriate supplier selection procedures. Despite, most of the decision makers have facing the challenges of both tangible and intangible factors affects the business operations and leading one another vagueness and complex nature [16] & [17] &
The supplier selection has major obstacles in information inaccuracy and criticality to time based decision taken by more uncertain and complicated demand patterns [19]. The various SC strategy direct impacts on the supplier—buyer relationships. The propose SC strategy has provided firms production growth economical and global competitiveness to sustain continuous change business environment. The strategy can strengthen firm’s capability, business performance and firms’ competitiveness in volatile market demand. [20]. Mason-Jones investigates different types of SC such as lean, agile and leagile. The adaption of lean SC was consist of value stream mapping, and eliminate wastes and reduces the buffer cost in the Supply Chain. Therefore, lean SC has enhanced the process of efficiencies and competitiveness of production to sustain the economies of scale of competitive advantage in market system [21]. Agile SC has more responsive to fulfilling the customer expectation of various innovative and customized product to customer satisfaction of various variety [22]. The customer demand variations and postponement strategy have reinforcement to assembly process unless until adequate demand information is enrichment. The various applications namely, fashion industry, computer games and music CD industries uses in this strategy [23]. The ASC strategy has provided more flexibility and market demand fulfilled strategy. The three categories of SC strategies classified such as ASC, Efficient SC, and Responsive SC. Finally, adoption of agile supplier selection has force driver of fast market responses and quick responses of new product developed and better market penetration strategy.

2. The fuzzy DEMATEL Method

DEMATEL approach is a suitable fit for constructs and analyses a structure model examines the influence among the complex factors. The extension of DEMATEL approach is making a decision in Fuzzy environment and fuzzy logic judgement procedure adopted [24]. The Fuzzy DEMATEL approach has implemented tool found a more precise analysis work. This methodology explains the diagraph concepts, which separates into cause and effect group criteria. The diagraph concepts may be potentially viable to explore the contextual relationship among the system, which examine the potentially strength each factors influences. The qualitative study to examine the effectiveness of cause and effect influence factors through mapping data based system [25]. This methodology evaluates agile supplier performance criteria are identified the key factors criteria for agile the supplier performance criteria and information flow in SC multi-tiers network for better decision making in supplier selection of SCM. This methodology is transformed the relationship b/w cause and effect group criteria into the intelligent structure model of the system initiatives. Let us consider a set of elements R = \{R_1, R_2, R_1, \ldots R_n\}, and pair wise relations are examined by modelling w.r.t mathematical relation S. The notation 0 means in the cell (i,j) in such a situation of entry is a positive integral that defined by (1), and the ordered pair (R_i, R_j) is established a relation S. There potential a relation in the element K_i that effects element R_j. The method is using for analysing the data in this scenario and refine the essential steps below. The designing of influence are such as “very low influence”, “low influence”, “high influence”, “very high influence” respectively.

Where T- direct relation matrix (DRM), Where T = [T_{ij}]_{n \times n} then normalized DRM, A = [A_{ij}]_{n \times n} and 0 \leq S_{ij} \leq 1

\[
K = \frac{1}{\max_{1 \leq i < n}\sum_{j=1}^{n} a_{ij}} \quad (1)
\]

\[
S = R \times T, \quad (2)
\]

Identified the total relation matrix M, Where I is identity matrix.

\[
M = X (I - X)^{-1}, \quad (3)
\]

Identified the total relation matrix M, Where, R-the sum of row, & C- The sum of columns,

\[
M = m_{ij}, \quad i_j = 1,2,3 \ldots \ldots , n. \quad (4)
\]

\[
C = [\sum_{j=1}^{n} m_{ij}]_{n \times 1}, \quad (5)
\]
\[ R = \left[ \sum_{j}^{n} m_{ij} \right] 1 \times n, \quad (6) \]

Where, D- The sum of row, R- the sum of columns, the cause effect graph can be obtained through mapping a database of respectively (C+R, C-R), where horizontal axis (C+R), and Vertical axis (C+R) shown. It suggested fuzzy set theory and explored the concept of membership function [26]. The membership function:

\[
\mu_x(y) = \begin{cases} 
0 & y < a, \\
\frac{(y-a)}{(b-a)} & a \leq y \leq b, \\
\frac{(c-y)}{(c-b)} & b \leq y \leq c, \\
0 & y > c,
\end{cases}
\]

According to fuzzy number refers to Fuzzy set on real line R and their membership function is \( \mu_x(y) \): R [0, 1], their exist flowing characteristics: \( \mu_x(Y) \) is piecewise continuous, \( \mu_x(Y) \) is convex fuzzy subset. Finally, we implement a variation of CFCS (converting fuzzy data into crisp score) defuzzification fuzzy aggregation procedure. The method has been more effective by researchers for arriving at crisp values [26][27]. The CFCS approach is implementing to examine the fuzzy max and min of the fuzzy number range. According to membership functions, the total score is occurring as weighted average. As consider \( A_{ij} = (l_{ij}^{0}, m_{ij}^{0}, r_{ij}^{0}) \), explore the degree of criteria i that affects the criteria j and fuzzy questionnaires n (n = 1, 2, 3 . . . p).

The five steps involved in CFCS method, which are following

First, step to implement normalization.

\[ x_{ij}^{n} = \left( r_{ij}^{n} - \min(l_{ij}^{n}) \right) / \Delta_{\min}^{\max}; \quad \text{Similarly, } x_{mij}^{n} \ldots \ldots x_{l ij}^{n} \quad (7) \]

Where \( \Delta_{\min}^{\max} = \max(x_{ij}^{n}) - \min(x_{ij}^{n}) \)

Second, step to implement normalized values

\[ x_{rs}^{n} = x_{r}^{n} / (1 + x_{l}^{n} - x_{m}^{n}) \quad (8) \]

\[ x_{ls}^{n} = x_{m}^{n} / (1 + x_{m}^{n} - x_{l}^{n}) \quad (9) \]

Third step to compute total normalized crisp values:

\[ x_{ij}^{n} = \left[ x_{rs}^{n} \left(1 - x_{ls}^{n}\right) + x_{rs}^{n} \times x_{rs}^{n} \right] / \left[1 - x_{rs}^{n} + x_{rs}^{n}\right] \quad (10) \]

Fourth, step to compute the crisp values:

\[ z_{ij}^{n} = \min(y_{ij}^{n}) + x_{ij}^{n} \times \Delta_{\min}^{\max} \quad (11) \]

Fifth step to implement integrate crisp values

\[ z_{ij} = \frac{1}{p} (z_{ij}^{1} + z_{ij}^{2} + \ldots + z_{ij}^{p}) \quad (12) \]

The framework of agile supplier performance criteria (competitive factors and organizational factors) has depicted in the Figure 2. The business strategy adoption of ASC is significant role-play in volume flexibility and market driven strategy. Therefore, agile supplier performance criteria are separate into two parts (i) Competitive factors and (ii) Inter organizational factors.

The following steps are involved to identify the cause and effect relationships.

**Step 1:** With the help of expert terms, we generate the Fuzzy direct relation matrix (DRM). The influence score is inserting in the particular cells, in Five-point Likert scale.

**Step 2:** Using of Software MATLAB R2014a to calculate the complex matrix solution.

**Step 3:** After fuzzy DRM generated than we replace and influence scores and trapezoidal intuitionistic fuzzy number (TrIFNs), then triangular fuzzy number has produced.
Step 4: With the help of average crisp matrix, we generate initial DRM. It represents the initial DRM.  
Step 5: After we generate initial DRM, than normalized DRM should be consist and found DRM.  
Step 6: With the help of normalized DRM, we generate final of Total relation matrix T, it has depicted in Table3, and finally it represent the Total relation matrix T developed.  
Step 7: The identified of total matrix T, we have developed prominence and relation vector.  
Step 8: Finally, we have developed a cause effect diagram of ASS criteria, it shows in the Figure3, eventually, it represents ranking of cause and effect groups of agile supplier criteria. The cause and effect groups are significant role for manager level interventions of multi tiers supply network agile supplier performance criteria preference decision.

| Competitive factors | Inter Organizational factors |
|---------------------|----------------------------|
| Cost satisfaction (A11) | Buyer-supplier relationship (A1) |
| Cost minimization (A5) | Supplier innovativeness (A2) |
| Qualities improvement (A6) | Information Technology tools (A7) |
| Lead-time reduction (A4) | Logistic (A10), |
| Delivery speed (A3) | Total cycle time compression (A13) |
| Pricing (A8) | Virtual Integration (A14) |
| Minimizing Uncertainty Situation (A9) | Data accuracy (A12) |

**Figure 1**, Agile supplier selection of performance criteria

**Figure 2** Flow chart of agile supplier selections criteria using Fuzzy DEMATEL
3. Conclusions

The outcomes of this paper to identify the cause group criteria (C-R) has found positive potential factors sequences such as Buyer-supplier relationship (A1), Supplier innovativeness (A2), Lead time reduction (A4), Information Technology Tool (A7), Minimizing uncertainty situations (A9), Data accuracy (A12). These identify factors sequence has positive influence on the agile supplier selection procedure in multi tiers supply chain networks. Similarly, the cause group criteria (C-R) has found negative factors sequences such as Delivery speed (A3), Cost minimization (A5), Quality improvement (A6), Pricing (A8), Logistic (A10), Customer satisfactions (A11), Total cycle time compression (A13), Virtual integration (A14). These identify factors have negative a potential influence on the agile supplier selection process. It also motivate to the inter origination business activities have improved by adaptation of these factor under considerations. They identify that the effect group criteria has directly affected by agile supplier selection criteria in multi-tiers suppliers' networks. Identify cause and effect groups’ criteria overcome of uncertain market demand and volatile market situation in multi tiers supply chain networks. These identify effect group criteria (C+R) has explores the relatively significant role of agile supplier selection practices in multi tiers supply chain networks for innovative product production. The buyer supplier relationship is identifying the highest score depicted in Figure 3. These are identify that effect group criteria have found positive sequence namely, Information Technology Tool (A7), Supplier innovativeness (A2), Lead time reduction (A4), Data accuracy (A12), Minimizing uncertainty situations (A9), Cost minimization (A5), Quality improvement (A6), Similarly manner have ranking of the (C-R) priorities such as Pricing (A8), Total cycle time compression (A13), Delivery speed (A3), Cost minimization (A5), Quality improvement (A6), Customer satisfaction (A11), Logistic (A10), Virtual integration (A14). Hence, identify the ranking of cause and effect groups are divided into two parts, where first part proposed the cause group of ranking of agile supplier criteria are such as Pricing, total cycle time compression, Delivery speed, Cost minimization, quality improvement, logistic, customer satisfaction, virtual integration. The second part represents of effect group ranking the agile supplier criteria namely, buyer-supplier relationship, Information technology tool, Supplier innovativeness, lead-time reduction, data accuracy, minimizing uncertainty situation. The outcomes of cause and effect group criteria can significant

![Figure 3 Cause and Effect group criteria relation in agile supplier selection](image-url)
contribution in managerial skill to better decision planning such as multi resource utilization, finance investment, data accuracy, forecasting planning, reactive, and proactive planning strategies in market uncertainty, lumpy demand and customer satisfaction environment. Managers are able to understand the agile supplier selection practices based on multi-tiers complex supply network to flow smoothly and match the target level to achievement. The complete adaptation of ASS is more expensive, and complicated subjects due to strategic and operational activities affected by agile supplier selection criteria such as, supplier-buyer relationship, supplier innovativeness, data accuracy, total cycle time compression, and delivery speed. The manager can benefited by developing the ability of knowledge management, effective information sharing b/w multi-tiers supplier network, quick decision making and problem solving tools, which helps to improve the performance of inter-organization and competitiveness factors. Managers also decide the financial support to develop the agile supplier capability to achieve the market requirement and customer satisfaction. The further extension of agile supplier selection procedure can be implementing in cross docking strategies for logistic network integration to improve the SC performance in apparel Industry and cosmetic industry in the Indian context.

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