G-Resilient Supplier Selection in Fuzzy Environment: Application Potential of Satisfaction Function and Distance Based Approach

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***Abstract*—A novel decision support framework has been proposed herein to solve supplier selection problems by considering green as well as resiliency criteria, simultaneously. In this work subjectivity of evaluation criteria has been tackled by exploring fuzzy set theory. A satisfaction function and distance based approach has been conceptualized in this work to operate under fuzzy environment. Application potential of the proposed fuzzy decision making approach has been compared to that of Fuzzy-TOPSIS**

***Index Terms*—Fuzzy-TOPSIS, Satisfaction Function, Distance Based Approach**

I. Introduction

Managing the movement of goods or products from one point to another subjected to certain constraints is well acknowledged as supply chain management (SCM). In a broader sense, ensuring the synchronization between various network activities from the beginning to the destination is referred to as supply chain management. In traditional supply chain, huge industrial wastes resulted in high level of environmental pollution. In order to save environment and also the Earth, green concepts were introduced; traditional supply chain was reoriented as green supply chain. The primary motivation for consideration of green supply chain management (GSCM) is to diminish environmental deterioration throughout the product life cycle. GSCM intends to eliminate various industrial wastes including hazardous chemical, emissions, energy and solid waste along every network activities such as product design, material resourcing and selection, manufacturing process, delivery of final product and end-of-life management of the product [1-2].

Supply chain performance can be enhanced by adopting green practices which in turn results better cost saving and profitability. Adding the ‘green’ component to supply chain management involves addressing the influence and relationships between supply chain management and natural environment [2]. It is well understood that a firm cannot survive in long run without supplier’s contribution as they are the dealer who supply necessary goods and services that the firm can’t self-produce [3]. Selection and management of appropriate supplier is the key to acquire desired level of quality products at the reasonable price with on time delivery. Thus to support GSCM, supplier selection should emphasize on supplier’s ability to adopt green concepts like green image, green competencies, green packaging, environmental management and capability of preventing pollution. However, Reference [4] proved that the green paradigm is concerned with environmental risks and environmental impact reduction only and does not consider the effects of disturbances on the system. Afterward to handle the disturbances on the system, Reference [5] introduced the concept of resilient supply chain and highlighted resilient paradigm which focuses on the supply chain ability to recover to the desired state after occurrence of a disruption occurs. Disruption is a Low Probability High Intensity Event (LPHI) which may cause system unbalance (turbulence) for a long term. Therefore, preparation for sustaining in disruption situations should also be considered as a critical strategic issue in supplier selection process. Thus, proactive arrangement for these sorts of happenings should be a priority for supply chain managers [6]. Resiliency is an adaptive control term where firms prepare themselves to cope up with any unexpected event or demand by assuring continuity of the operation at the best possible rate. It is also described as the capacity of a system to attain its original state after disruption is incurred. According to Reference [7], resiliency refers to a firm’s capacity to survive, adapt and grow in the face of change and uncertainty.

Literature is very limited in applying integrated decision support tools on the deployment of green and resilient strategies simultaneously, particularly for the supplier selection problem. Supplier selection process may include quantitative/qualitative information (or combination of both); to handle the situation, past researcher developed numerous decision making tools and techniques seemed helpful to provide realistic solutions. Quantitative information or criteria can be evaluated by applying traditional multi-criteria decision making (MCDM) methodologies; whereas, qualitative criteria information were analyzed in fuzzy/grey environment. In this context, a novel decision support framework based on satisfaction function and distance measure concept [8-10] has been delineated herein to facilitate g-resilient supplier selection in fuzzy environment. The application potential of the proposed decision support module has been compared to that of Fuzzy-TOPSIS. The preliminary fuzzy mathematics could be retrieved and understood from [11-15].

II. CASE EMPIRICAL RESEARCH

A case empirical analysis has been demonstrated here to verify application potential of the proposed decision support module. The study articulates a supplier selection problem in consideration with green as well as resiliency criteria. It has been assumed that every candidate suppliers have achieved the requirements of traditional performance criteria (product price, delivery time, quality and service) of similar extent and hence, the best supplier has to be chosen in view of green as well as resiliency criteria. The following criteria: Use of environment friendly technology (C_1),
Use of environment friendly materials (C_2), Green market share (C_3), Partnership with green organizations (C_4), Management commitment (C_5), Adherence to environmental policies (C_6), Green R & D projects (C_7), Staff Training (C_8), Lean process planning (C_9), Design for environment (C_{10}), Environmental certification (C_{11}), and Pollution control initiatives (C_{12}) etc. have been considered as green criteria. Similarly, the following criteria: Investment in capacity buffers (C_{13}), Responsiveness (C_{14}), Capacity for holding strategic inventory stocks for crises (C_{15}) etc. have been considered as resiliency criteria. Assuming a group of four decision-makers (DMs) have been employed to evaluate four candidate suppliers (S_1, S_2, S_3, S_4) in view of aforementioned green as well as resiliency criteria (C_1 to C_{15}); a 7-point fuzzy linguistic scale has been chosen to collect subjective judgment of the individual member of the decision-making group in regards of criteria weight as well as rating of alternative suppliers with respect to evaluation criteria. The following linguistic terms set: Very Low (VL), Low (L), Medium Low (ML), Medium/ Moderate (M), Medium High (MH), High (H) and Very High (VH) have been explored towards assigning criteria weights; and the linguistic terms set: Very Poor (VP), Poor (P), Medium Poor (MP), Fair (F), Medium Good (MG), Good (G) and Very Good (VG) have been used to assess ratings of alternative suppliers with respect to various criteria. The aforesaid two linguistic terms sets along with their fuzzy representations have been depicted in Table I.

Table I: Seven point fuzzy linguistic scale for quantifying criteria rating and priority weights

Linguistic terms for criteria ratings	Linguistic terms for assigning criteria weights	Generalized trapezoidal Fuzzy Numbers
Very Poor, VP	Very Low, VL	(0,0,0.1,0.2)
Poor, P	Low, L	(0.1,0.2,0.2,0.3)
Medium Poor, MP	Medium Low, ML	(0.2,0.3,0.4,0.5)
Fair, F	Medium/ Moderate, M	(0.4,0.5,0.5,0.6)
Medium Good, MG	Medium High, MH	(0.5,0.6,0.7,0.8)
Good, G	High, H	(0.7,0.8,0.8,0.9)
Very Good, VG	Very High, VH	(0.8,0.9,1,1)

Assuming the decision-making group has been instructed to utilize those linguistic scales for assigning criteria weights and ratings of alternatives in terms of linguistic variables. Since all the evaluation criteria being subjective in nature; such kind of linguistic assessment is well justified. However, linguistic human judgment always bears some degree of uncertainty in terms of incompleteness as well as inconsistency; therefore, ambiguity and vagueness of imprecise data can efficiently be dealt with fuzzy set theory. Hence, linguistic decision making information as provided by the expert group has been converted into appropriate fuzzy numbers (Table I); then, by exploring fuzzy decision making approaches, the final decision outcome is achieved. In this work, first linguistic data have been transformed into appropriate fuzzy numbers in accordance with Table III. By using fuzzy aggregation rule, aggregated fuzzy ratings of alternatives with respect to criteria have been computed; thus, initial decision support matrix has been arrived. Similarly, aggregated fuzzy weights of criteria have been computed. Assuming all evaluation criteria as beneficial (Higher-is-Better; HB) in nature, aggregated fuzzy ratings of alternatives (with respect to evaluation criteria) have been converted into normalized fuzzy ratings. The normalized fuzzy rating of criteria have been multiplied with corresponding criteria weight; thus to obtain the weighted normalized decision matrix. By considering fuzzy ideal solution (1,1,1,1), the separation measure of each alternative with respect to ideal criteria values have been computed next. Satisfaction values of each alternative with respect to individual criteria have thus been computed (Table II). In this computation, satisfaction values have been computed based on HB requirement type [10]; as shown in Fig 1. After calculating satisfaction value of individual criteria for alternative.

Table II: Satisfaction values of each alternative with respect to individual criteria.

Criteria	Satisfaction values of individual alternatives			
	S_1	S_2	S_3	S_4
C_1	1.0000	0.2435	0.6149	0.2134
C_2	0.6626	0.2367	0.1825	0.5939
C_3	0.8628	0.8588	0.5983	0.9793
C_4	0.2523	0.6158	0.2976	0.0867
C_5	0.2767	0.0000	0.5128	0.6782
C_6	0.4290	0.5974	1.0000	0.8512
C_7	0.1521	0.8648	0.5003	0.2765
C_8	0.5782	0.3104	0.3129	0.6652
C_9	0.2494	0.5983	0.0000	0.8988
C_{10}	0.5421	0.9997	0.3347	0.2134
C_{11}	0.0000	0.5684	0.2661	0.2929
C_{12}	0.1097	0.0665	0.4410	1.0000
C_{13}	0.5010	0.1736	0.8802	0.6431
C_{14}	0.6456	0.1655	0.7508	0.7182
C_{15}	0.2859	0.0904	0.2667	0.0000

suppliers, total distance measure has been calculated. Alternative suppliers have been ranked according to the total distance measure (Lower-is-Better; LB type). The ranking order appears as: $S_4 > S_3 > S_1 > S_2$; the most appropriate choice seems the same as obtained in Fuzzy-TOPSIS (Table III).

Table III: Ranking order of g-resilient suppliers

Alterna-tives	Total distance measure	Ranking order (Proposed approach)	CC_i (Closeness coefficient)	Ranking order (Fuzzy-TOPSIS)
S1	2.4265	3	0.431455	4
S2	2.5306	4	0.474306	3
S3	2.3106	2	0.60475	2
S4	2.1715	1	0.648154	1

III. CONCLUSION

In the present work, a g-resilient supplier selection framework has been anticipated in view of a decision making scenario aiming to select the best g-resilient supplier by considering green as well as resiliency criteria. Subjectivity of suppliers evaluation criteria have been carefully explored by means of fuzzy set theory. The work exhibits application potential of a novel decision support framework i.e. satisfaction function and distance based approach in the context of g-resilient supplier selection. The ranking order of candidate g-resilient suppliers as obtained has been compared to that of Fuzzy-TOPSIS. Supply chain managers are hereby advised to adopt the guidelines prescribed herein for solving complex decision making problems.

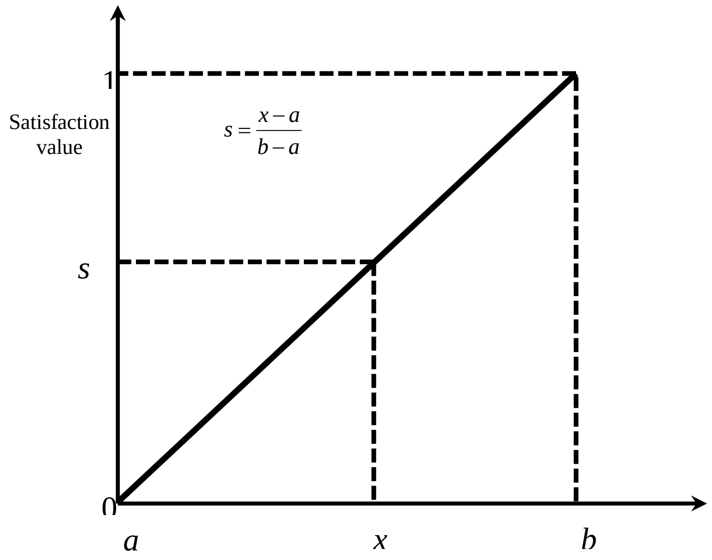

Fig. 1: Degree of satisfaction chart for a characteristic where the maximum value provides the best satisfaction (Higher-is-Better, HB)

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