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# Supplier selection in resilient supply chains: a grey relational analysis approach

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ABSTRACT

Suppliers can be considered as inevitable sources of external risks in modern supply chains. In this context, resilience that stands for the adaptive capability to respond to disruptions and recovering from it needs to be considered in supplier selection. But selection of suppliers is a challenging issue that involves the evaluation of both qualitative and quantitative attributes, in usual have imprecise and limited information. Grey relational analysis based on linguistic assessment of supplier rating and attribute weightings could judiciously be used under these situations to obtain a set of possibility values for prioritizing supplier selection. In this research, a supplier to be selected in the context of a resilient supply chain is termed as a resilient supplier. Taking electronic supply chain as a case study, with six alternative suppliers, grey possibility values for supplier selection were calculated and the suppliers were prioritized. Sensitivity analysis was also conducted to identify how far the selection priorities of suppliers change by varying the weightings given to each of the resilience attributes. This helps us in identifying the attributes of resilience where a particular supplier performs well. A comparison of proposed grey methodology with analytic hierarchy process (AHP) and analytic network process (ANP) was also conducted to comprehend extent of out-performance. The results of the proposed research could help top management in taking strategic level decision making with respect to selection of suppliers in a resilient supply chain.

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## 1. Introduction

Supplier Relationship Management (SRM) includes all processes including evaluation and selection of supplier, negotiations of pricing and delivery, sharing of demand and supply etc. (Chopra and Meindl, 2007). Modern supply chains are not simple chains or series of processes, but are complex networks where disruptions can occur at any time. This increases the risk associated with supply chains. The sources of risks can be at four levels, (i) process and value stream related risks, (ii) assets and infrastructure related risks, (iii) organizational and inter-organizational risks and (iv) risks related with the environment (Christopher, 2004).

Disruptions can occur in supply chain from both internal and external sources. Suppliers in most cases are inevitable sources of external risk. Selection of suppliers is a Multi Criteria Decision-Making (MCDM) problem that involves consideration of both qualitative and quantitative attributes. Supplier selection done by giving greater priorities to risk related issues reduces vulnerability of supply chain to a great extent. Real time risk management process should involve the following, (i) risk identification, (ii) risk assessment, (iii) risk mitigation and (iv) risk monitoring (Matook et al., 2009). Resilience, which is the ability of the system to return to its original state or a better one after being disturbed, assumes great significance in this context (Christopher and Peck, 2004). Hamel and Valikangas (2003) view resilience as a distinct source of sustainable competitive advantage for suppliers. The ability of suppliers to manage risks, i.e. being better positioned than competitors to deal with disruptions is the essence of supplier resilience (Sheffi, 2005).

Selection of suppliers for resilient supply chains needs to address some important questions, as (i) Why does a supplier need to be resilient in nature? (ii) Can the level of resilience for a particular supplier be measured? (iii) What are the parameters a company needs to consider in supplier selection for building resilience? Answering these questions was the primary aim of this research. No literature has been found till date for selection of supplier using multi attribute decision making (MADM) tools in the

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**Nomenclature**

| | |
|---|---|
| $\otimes G_{ij}$ | *Average grey rating of the 'j*th*' 'Supplier Resilient Attribute' (SRA) of the 'i*th*' supplier* |
| $\otimes G_{ij}^{k}$ | *Grey number associated with* $G_{ij}^{k}$ |
| $\otimes G_{ij}^{*}$ | *Normalized grey ratings of* $\otimes G_{ij}$ |
| $\otimes W_j$ | *Average grey weight of the 'j*th*' SRA* |
| $\otimes W_j^k$ | *Grey number associated with* $W_j^k$ |
| $\otimes V_{ij}$ | *Weighted normalized grey rating of* $\otimes G_{ij}$ |
| $A_k$ | *Set of 't' analyst committee members,* $k = 1, 2, 3, \ldots, t$ |
| $D$ | *Grey decision matrix of average ratings,* $\otimes G_{ij}$ |
| $D^{*}$ | *Grey decision matrix of the normalized average grey ratings,* $\otimes G_{ij}^{*}$ |
| $D^{**}$ | *Grey decision matrix of the weighted normalized average grey ratings,* $\otimes V_{ij}$ |
| $\underline{G}$ | *Lower limit of the grey number,* $\otimes G$ |
| $\overline{G}$ | *Upper limit of the grey number,* $\otimes G$ |
| $G_j^{min}$ | *Minimum value of* $\underline{G}_{ij}$ *among the suppliers,* $i = 1, 2, 3, \ldots, m$ |
| $G_j^{\max}$ | *Maximum value of* $\overline{G}_{ij}$ *among the suppliers,* $i = 1, 2, 3, \ldots, m$ |
| $G_{ij}^{k}$ | *'j*th*' SRA rating for the 'i*th*' supplier by the 'k*th*' analyst in linguistic terms,* $i = 1, 2, 3, \ldots, m$; $j = 1, 2, 3, \ldots, n$; $k = 1, 2, 3, \ldots, t$ |
| $L_j^{*}$ | *Sum of the lengths of 'j*th*' grey numbers,* $\otimes V_{ij}$ *and* $\otimes G_j^{\max}$, $j = 1, 2, 3, \ldots, n$ |
| $L(\otimes G)$ | *Length of the grey number* $\otimes G$ |
| $S_i$ | *Set of 'm' supplier alternatives,* $i = 1, 2, 3, \ldots, m$ |
| $S^{\max}$ | *Ideal referential set of supplier alternatives,* $\{G_j^{\max}\}$, $j = 1, 2, 3, \ldots, n$ |
| $SRA_j$ | *Set of 'n' Supplier Resilient Attributes (SRA),* $j = 1, 2, 3, \ldots, n$ |
| $W_j^k$ | *Weight of 'j*th*' SRA assigned by 'k*th*' analyst in linguistic terms,* $j = 1, 2, 3, \ldots, n$; $k = 1, 2, 3, \ldots, t$ |

context of resilient supply chains. An attempt in this regard could enhance resilient capabilities of firms. This has motivated us to develop a model for the same.

Grey relational analysis (GRA) methodology can be used to combine both qualitative and quantitative attributes by considerations of *larger - the better* or *smaller - the better* evaluation criteria (Yang and Chen, 2006). Grey relational methodology is well applied in decision making in almost all multi attribute decision making problems (Wu, 2002). It has an added advantage in supplier selection problem, as it includes the evaluation of both qualitative and quantitative attributes. We have used grey relational analysis in this research for supplier selection in the context of a resilient supply chain. This methodology results in a set of possibility values by comparing the performance of suppliers in resilience with an ideal referential supplier. Simple linguistic scales are needed as input for comparison, to generate possibility values in numeric figures thereby making the decision making tranquil for managers. Increasing order of possibility values are indicators of decreasing probabilities for supplier selection.

In this research, the attributes imparting resilience capabilities to the suppliers were identified in the context of an electronic supply chain. It was also tested in an electronic manufacturing company, ABC. The electronic supply chains can be considered extremely vulnerable on power failure, short circuits or any other kind of catastrophes. The absence of even a single component can bring the production to a complete halt. Thus, suppliers play an important part in electronic supply chains. Having a resilience property decreases the vulnerability of the supply chains.

This paper is further organized as follows; Section 2 describes the literature review on supplier selection models and parameters for supplier selection in resilient supply chains. The framework of resilience imparting attributes taken into consideration for the selection of a supplier in the context of an electronic supply chain is given in section 3. Section 4 describes the procedure for grey relational analysis in supplier selection. Section 5 demonstrates the application of the proposed framework for supplier selection in a real case electronics manufacturing company. Section 6 discusses the managerial implications of this research, which is followed by the conclusions and scope of future work.

## 2. Literature review

Supply chain management is a complex function incorporating wide variety of risks, ranging from minor risks such as delays to major risks such as disruption of entire chain (Waters, 2011). Understanding and managing the processes that comprise supply chains is critical for reduction of potential risks (Christopher and Peck, 2004). Lee (2002) proposed triple 'A' principle of '*Alignment, Adaptability* and *Agility*' as strategies for supply chain resilience. Asbjørnslett (2009) allied efficiency and vulnerability as, 'the more efficient the supply chain is, the more it is vulnerable towards risks'. Tang (2006) has identified flexible supply base as one of the primal enabler of supply chain resilience. Blackhurst et al. (2005) identified eighteen strategies for risk management and pointed the need of suppliers for handling vulnerability related issues in supply chains. There is always uncertainty about the supplier vulnerability and thus supplier resilience is necessitated (Ponomarov and Holcomb, 2009). Tang and Tomlin (2008) vividly points role of flexibility in managing various kinds of risks, by mentioning types of flexibilities needed and the mitigating strategies to be adopted for each type of risk.

Christopher and Lee (2004) mentioned role of suppliers in imparting resilience to supply chains and stressed on the necessities of having a collaborative relationship with suppliers. According to them, risk mitigation is possible through suppliers with high visibility. Sheffi (2005) analyzed factors critical to the design of a resilient supply chain and addressed the essentials of having flexible supply chains. Also, risks can better be distributed and mitigated if the supply chain has a large supplier network. Peck (2005) pointed out that high levels of collaboration with suppliers can improve resilience; thereby increasing risk hedging capabilities of supply chains. Moore and Manring (2009) addressed sustainability aspects of a resilient supply chain and stressed that issues related to environment and sustainability should be considered for developing supplier selection strategies for Small and Medium sized Enterprises (SME's).

Banker and Khosla (1995) classified supplier selection process as an important decision making area in operations management. Choi and Hartley (1996) explored the supplier selection practices used by firms at various levels in the supply chain. Verma and Pullman (1998) analyzed the supplier selection process based on relative importance of different attributes such as quality, price, flexibility and delivery performances. Ghodsypour and O'Brien (1998) considered both qualitative and quantitative factors and made trade-off between both tangible and intangible factors for selection of suppliers. De Boer et al. (2001) presented a literature on decision making methods for supplier selection process considering all stages from initial problem definition to final choice among qualified suppliers.

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