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An integrated fuzzy approach for prioritizing supply chain complexity drivers of an Indian mining equipment manufacturer

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ABSTRACT

The complexities in present day supply chain are numerous and are evolving due to globalization, customisation, innovation, flexibility, sustainability and uncertainties. The growing supply chain complexity results in negative consequences on cost, customer service and reputation. Managing supply chain complexity without compromising the profitability is a challenging task. Supply chain complexity (SCC) management involves identifying, prioritizing, measuring, analysing and controlling/eliminating the drivers of complexity. The SCC drivers denote number and variety of suppliers, customers, products, processes and uncertainties which are highly interdependent. Firms need to prioritize the drivers in order to manage and simplify SCC. Models and methods to prioritize the complexity drivers considering their interdependence are limited in literature. Prioritizing the complexity drivers requires a subjective approach and it is a multi criteria decision making (MCDM) problem. In this research, at first a fuzzy ISM (Fuzzy Interpretive Structural Modelling) is used to establish the interdependence of SCC drivers. A fuzzy AHP (Analytic Hierarchy Process) and fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) are then used to quantify and prioritize the complexity drivers considering the strength of interdependence obtained using the fuzzy ISM. A case example of a mining equipment manufacturer located in India is presented to illustrate the proposed approach. From the results it is identified that unreliability of suppliers, forecast inaccuracy, lack of visibility /information sharing and number/variety of processes are the significant drivers.

1. Introduction

A supply chain is a complex network of facilities designed to procure, produce and distribute goods to customers at right quantities, to the right locations and at the right time. Supply chain complexity (SCC) can be defined as all operational uncertainties and/or structural varieties associated with internal or external causes by the information and/or material flows along the supply chain that are known, unknown, expected, unexpected, predicted or unpredicted (Isik, 2010). The complexities in the present day supply chain are numerous and are evolving due to globalization, variety, flexibility, sustainability and uncertainties (Blome et al., 2013; Christopher, 2016; Gunasekaran et al., 2014; Hashemi et al., 2013). The increasing SCC leads to supply chain disruption (Bode and Wagner, 2014), soaring supply chain cost (De Leeuw et al., 2013) and poor customer service (Bode and Wagner, 2014; De Leeuw et al., 2013). Studies conducted by PricewaterhouseCoopers (2012) and Kearney (Shivaraman et al., 2013) highlights that managing SCC is significant to gain competitive advantage. Following the work of Isik (2011) the strategies/steps to effectively manage supply chain complexity involves identifying, prioritizing, measuring, and controlling the drivers/sources of complexity. A supply chain complexity driver is any property of a supply chain that increases its complexity (Serdarasan, 2013). Decision maker can implement right strategies for managing the complexity by analysing/ understanding the complexity drivers and their interdependence (Vogel and Lasch, 2015). Thus identifying all the complexity drivers and their interrelations that lead to unpredictable outcomes in supply chain is the first step in managing the complexity. Firms within supply chain are interested to address the dominant drivers rather than addressing all the drivers (Subramanian et al., 2014). To identify the dominant drivers the SCC drivers are to be ranked or prioritized considering their relative importance on the supply chain performance (Kavilal et al., 2014). Prioritizing the complexity drivers requires a subjective approach and it is a multi criteria decision making (MCDM) problem. Several MCDM methods have been proposed in the literature and among them the outranking approaches are appropriate for ranking applications. PROMETHEE (Brans and Mareschal, 2005; Maity and Chakraborty, 2015) is reported to be more stable among

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outranking methods. The implementation of PROMETHEE requires the information on criteria weights and the choice of preference functions with their parameters. With PROMETHEE no specific guidelines are available to determine criteria weights and the parameters of different preference function (Podvezko and Podviezko, 2010). To overcome the above limitations of PROMETHEE we propose an integrated methodology combining PROMETHEE with the favorable characteristics of AHP (Macharis et al., 2004) and ISM (Bouzon et al., 2015; Luthra et al., 2015). In this work, the parameters of the PROMETHEE preference function are set by considering the interdependence between the SCC drivers. We thus use a fuzzy ISM and fuzzy AHP to obtain the parameters of the PROMETHEE preference function and criteria weights respectively. A fuzzy PROMETHEE is then used to prioritize SCC drivers. Fuzzy numbers are used in this study since human preferences are often subjective, imprecise and ambiguous (PrasannaVenkatesan and Goh, 2016; Tseng, 2013).

1.1. Supply chain complexity in mining equipment industry

Mining is one of the major contributors of economic development in many countries (Luthra et al., 2015). According to a recent report published by Allied Market Research (AMR, 2016) the mining activities are growing especially in Asia Pacific countries such as India, China and Australia. Mining equipment manufacturer supplies the equipments, intermediates and sophisticated services needed for the mining industry (Kaplan, 2012). The demand for mining equipment is growing and developing countries like China and India are emerging as a source of supply (Farooki, 2012). Typically a mining equipment supply chain consists of part and component suppliers, manufacturers, distributors and dealers. Mining equipment manufacturing requires heavy engineering skills and a huge capital. The research addressing supply chain issues in the mining equipment industry is limited. Smith (2011) investigated the fuel cost minimization, make or buy and outsourcing strategies to reduce the supply chain complexity of a coal mining equipment manufacturer and three other companies. Kaplan (2012) explored the technological capacity, competitive position and constraints of South Africans mining equipment sector based on technology and trade data along with extensive firm visits and interviews. Simatupang and Sridharan (2016) analysed the typical problems faced by the heavy equipment supply chain in Indonesia. Supply chain in the mining equipment industry is becoming increasingly complex due to more product variety, specialized processes, more number of suppliers and subcontractors, demand fluctuations, high interdependence with other industries and rising sustainability requirements (Syncron, 2015). For example, Caterpillar, Inc. being the largest manufacturer of mining equipment needs to maintain 5, 00,000 different spare parts /aftermarket products and to quickly deliver them to its customer around the world to minimize the downtime cost due to unexpected mining equipment breakdown (Habermann et al., 2015). Mining equipment industries are thus developing strategies to proactively manage the supply chain complexities in order to reduce cost and improve customer service while maintaining the product quality and variety. To effectively manage supply chain complexity the drivers/sources of complexity are to be identified and the dominant drivers are to be ranked. Literature has yet to provide any evidence of a published work that identifies and prioritize supply chain complexity drivers especially for a mining equipment industry. Thus our contribution to the existing literature on mining equipment supply chain is to propose an integrated decision making method to prioritize the SCC drivers considering the interdependence among the drivers. The purpose of this research is to identify various drivers that increase the supply chain complexity and to propose an integrated fuzzy based MCDM to rank the significant complexity drivers for a mining equipment manufacturer.

The research objectives are as follows:

- To identify the various complexity drivers that affects the supply chain performance.
- To establish the interdependence among the identified drivers.
- To suggest a hierarchy structural model of SCC drivers for the case company.
- To prioritize/rank the SCC drivers considering its interdependence.
- To present the research implications.

The rest of this paper is organised as follows. Section 2 presents review on supply chain complexity drivers, fuzzy ISM, fuzzy AHP and fuzzy PROMETHEE. The proposed fuzzy MCDM approaches are explained in Section 3. The case example and the results are presented in Sections 4 and 5 respectively. Discussion and managerial implications are reported in Section 6. Finally in Section 7, conclusions and areas of further research are proposed.

2. Literature review

2.1. Prioritizing supply chain complexity drivers

Supply chain complexity is defined as the level of detail and dynamic complexity exhibited by the products, processes and relationships that make up a supply chain (Bozarth et al., 2009). Detail complexity refers to the distinct number of components or parts that make up a system while dynamic complexity denotes the unpredictability of a system's response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system. Material and information flows represent the main complexity drivers within a supply chain because of uncertainty and variety (Isik, 2010). SCC drivers are typically classified as upstream, internal manufacturing and downstream drivers (Bozarth et al., 2009), internal, supply/demand interface and external drivers (Blecker et al., 2005; Serdarasan, 2013). Serdarasan (2013) reviewed the different complexity drivers that are present in food, chemical, electronics and automotive supply chains and reported the solution strategies to overcome complexity related problems. Subramanian et al. (2015) have used an importance–performance matrix analysis to cluster drivers of supply complexity in the Chinese manufacturing sector. Researchers have studied the effect of SCC drivers on supply chain performance (Bozarth et al., 2009) and supply chain disruption frequency (Bode and Wagner, 2014). Strong interdependence exists among SCC drivers and decisions targeting to control/reduce any one of the drivers may have a positive or negative effect on another driver (Serdarasan, 2013). To mitigate the negative effects of supply chain complexity the SCC drivers are to be prioritized/ranked considering their interdependence. Prioritizing the complexity drivers requires a subjective approach and it is a multi criteria decision making (MCDM) problem. Models and methods to prioritize the SCC drivers considering their interdependence are limited in literature as shown in Table 1. Among the reviewed papers opinion survey and AHP are commonly used while Wang and Zhang (2010) proposed a DEMATEL to study the cause and effect relation. To address this research gap we identify various complexity drivers that affect the supply chain performance, establish the interdependence among the identified drivers and prioritize the SCC drivers for an Indian mining equipment manufacturer.

Identification of SCC drivers: The SCC drivers are identified from the published literature. The bibliographic data bases used for the literature search includes: Google Scholar, ISI Web of Science, Science Direct, Springer, Emerald and Proquest. The search is based on the key word combinations like “supply chain complexity” AND “driver”; “supply chain complexity” AND “factors”. From the detailed literature review and from discussions with experts in the case company fourteen SCC drivers relevant to mining equipment supply chain are identified (See Section 4). The identified drivers are further classified as supply