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Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management

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ABSTRACT

This study aims to utilize the Decision-making Trial and Evaluation Laboratory (DEMATEL) approach to recognize the influential criteria of carbon management in green supply chain for improving the overall performance of suppliers in terms of carbon management. Thirteen criteria of carbon management with three dimensions were identified from literature review and interview with three experts at an electronics manufacturer. By considering the interrelationships among the criteria, DEMATEL was applied to deal with the importance and causal relationships among the evaluation criteria of supplier selection. Obtained results show that the criteria of management systems of carbon information and training related to carbon management are revealed to be the top two significant influences in selecting suppliers with carbon management competencies. By identifying the structures and interrelationships, it can offer an insight for managers to understand cause-effort relationships and allow to select suppliers who are capable of having competence in carbon management and to improve suppliers' performance.

1. Introduction

Contemporary supply management aims to maintain long-term partnership with suppliers, and use fewer but reliable suppliers (Ho et al., 2010); hence supplier selection and evaluation in supplier management is important because of the increasingly critical role in a firm success that is played by suppliers (Wagner and Johnson, 2004). Regarding the field of supplier selection, the key is to consider decision models as instruments for eliciting, communicating, and scrutinizing one's personal and subjective preference structure and uncertainties rather than a rigid format replacing this all (de Boer et al., 2001). As previously noted, firms should systematically embrace an evaluation model of supplier selection in determining potential and appropriate partners to maintain competitive advantage in the globalization trend.

Organizations have become increasingly aware of the propensity for environmental pollution incidents within their supply network to cost them in penalties; cleanup and consumer backlash (Simpson et al., 2007). Given the growing environmental concerns during the past decade, a consensus is emerging that environmental pollution issues accompanying industrial development should be addressed together with supply chain management, thus contributing to green supply chain management (GSCM) (Sheu et al., 2005). Generally, GSCM is understood to involve screening suppliers based on their environmental performance and doing business only with those that meet certain environmental regulations or standards (Rao, 2002). Supplier selection either in GSCM or sustainable supply chain management (SSCM) has been identified as significant in making purchasing decisions (Seuring and Müller, 2008; Hu and Hsu, 2010). An increasing number of authors have addressed supplier selection issues in green supply chain viewed from environmental perspectives (Noci, 1997; Enarsson, 1998; Walton et al., 1998; Zhu and Geng, 2001; Handfield et al., 2002; Humphreys et al., 2003a, 2003b; Rao, 2005; Wu et al., 2007; Hsu and Hu, 2009; Lee et al., 2009; Bai and Sarkis, 2010; Kuo et al., 2010). However, carbon management in supplier selection in GSCM is rarely explored, although it is crucial for firms to mitigate carbon risk through collaboration with suppliers.

With increased awareness of climate change in the green supply chain, the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI, 2009) reported that at least 80% of carbon emissions are produced in the total

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supply chain. Companies in different industry sectors are beginning to recognize the carbon issue as one of the critical factors in GSCM (Lee, 2011). By controlling the carbon footprint across a supply chain, Sundarakani et al. (2010) propose a model for of carbon emission calculation for firms in their operations to reduce carbon footprint. Wittneben and Kiyar (2009) emphasize that GHG emissions from suppliers require consideration to adequately assess the contributions of any business to climate change. According to the 2010 supply chain report from the Carbon Disclosure Project (CDP), more than half of its members surveyed said that in the future, they would cease doing business with suppliers that do not manage their carbon emissions. More recently, some CDP members have attempted to develop a way to address the impact of the green supply chain in electronics companies on climate change. At the end of 2007, Nokia Corporation has started collaborative work with its suppliers of components and contract manufacturers in the area of carbon dioxide emission (Nokia, 2009). Later, Dell and HP Corporation published aggregated supply chain GHG emissions through supplier engagement to report GHG emissions and establish reduction targets, including a lot of electronics manufacturers from Taiwan (Dell, 2009; HP, 2009). If suppliers fail to meet these requirements with Dell, suppliers can be impacted on the ranking and may be diminished potentially on ability to compete for Dell's business (Dell, 2009). Since suppliers of brand name companies, such as Nokia, Dell and HP are mainly from Taiwan, one of the most industrialized countries in the Asia-Pacific region and home to a large number of electrical and electronics manufacturers involved in original equipment manufacturing (OEM) and original design manufacturing (ODM) (Hsu and Hu, 2009), these electronics companies are subject to customer requests for carbon management either at organization or product level. Hence, the main risks and pressures OEMs and ODMs faced with their suppliers include carbon management in the green supply chain. Therefore, both types of manufacturers must select suppliers capable of delivering both high-quality products and competent carbon management. To solve this question, a comprehensive model of carbon management for supplier selection is necessary for managers to determining appropriate suppliers as a long-term collaborative partnership in the green supply chain.

Nevertheless, to the best of our knowledge, supplier selection in GSCM specifically considering carbon management competence in the electronics industry has never been found in previous literature. Most of the early literature may be limited to exploring the broad environmental criteria of either quantitative or qualitative property concerning environmental cost, production process, product, and management system. Some typical supplier selection models are illustrated below.

By incorporating green competence, environmental efficiency, green image, and life cycle cost into the supplier selection, the framework proposed by Noci (1997) designs green vendor rating systems for the assessment of environmental performance of suppliers. As later pointed out by Zhu and Geng (2001), environmental consideration of supplier selection is a key competitive issue for large and medium-sized enterprises, and thus it should be taken into account to maintain the long-term relationships with their suppliers. Similarly, considering the corresponding evaluation factors of environmental performances, Handfield et al. (2002) proposed an environmentally conscious purchasing decision tool to assist managers in understanding the trade-offs between environmental dimensions using the analytic hierarchy process (AHP). Moreover, Humphreys et al. (2003b) proposed a knowledge-based system to evaluate the supplier environmental performance, which includes several categories of environmental costs, management competencies, green image, green design, environmental management system, and environmental competencies. Presently, Rao (2005) pointed out that companies are embracing the concept of greening of suppliers in the South East Asian region, aiming to provide an insight into the extent of greening that has been implemented and the underlying reason for Asian companies to adopt increasingly. As further emphasized by Wu et al. (2007), environmental principles applicable to green supplier evaluation have been proposed using the AHP and fuzzy logic. Their study considers the complete environmental impact of a product during its entire life cycle. By incorporating the issue of hazardous substances into green supplier selection, Hsu and Hu (2009) utilized the analytic network process (ANP) method to construct an evaluation framework of supplier selection in a Taiwanese electronics company, including five main criteria, namely, procurement management, research and development (R&D) management, process management, incoming quality control, and management system. Lee et al. (2009) propose an integrated model that adopts environmental and non-environmental criteria for selecting a green supplier in the high-tech industry. These criteria include quality, technology capability, pollution control, environmental management, green product, and green competencies. Similarly, Bai and Sarkis (2010) integrated a number of sustainability factors into the model of supplier selection that include economic, environmental, and social issues. They show particular interest in the field of social dimension, where employment practices, health and safety, local communities influence, contractual stakeholders influence, and other stakeholders influence are covered. However, these previous studies may still be limited to either the broad environmental criteria or integrating criteria because they fail to consider the carbon management issue while evaluating the corresponding green supplier operation.

By proposing a proper model for managing suppliers in supply chain, it is significant for firms to recognize outstanding suppliers for establishing long-term collaborative partnerships with these suppliers to increase competitiveness (Shin et al., 2000). However, Chang et al. (2011) argued that few methods and studies are capable of demonstrating the relationship between criteria that might affect supply chain management (SCM) performance. Their study utilized fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method to recognize key influence criteria in selecting suppliers, which can help enterprises to forecast suppliers in terms of the observation on influence of criteria. With the structural relationships among criteria has constructed for supplier selection, firms can obtain a clear understanding of the cause-effect relationship for facilitating suppliers' carbon management. By considering the interrelationship among the criteria for green supplier selection, previous studies rarely utilize systematic methodology to recognize and reflect more realistic results among decision attributes and alternatives. Because of the interdependent relationships exists in the real supplier selection and evaluation environment. To solve this problem, the interrelationship among criteria of carbon management in supplier selection will be considered in this present study. The DEMATEL approach has been considered one of the best tools to deal with the importance and causal relationships among the evaluation criteria (Fontela and Gabus, 1974; Chiu et al., 2006; Liou et al., 2007; Tzeng et al., 2007; Wu and Lee, 2007; Lin et al., 2009). The reason for the DEMATEL application choice comes from its ability to confirm interdependence among considered factors, and its ability to derive a direct graph showing the interrelationships among factors (Lin et al., 2009). With respect to supplier selection in the supply chain management (SCM), the DEMATEL can find key criteria to improve performance and provide decision-making information (Chang et al., 2011). The significance of incorporating carbon management into supplier selection as well as the limitation of previous studies justify the application of the DEMATEL methodology to construct a carbon management model for supplier