Journal of Cleaner Production xxx (2014) 1–9

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Building an effective system for carbon reduction management

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ARTICLE INFO

Article history:
Received 4 June 2014
Received in revised form
26 August 2014
Accepted 13 October 2014
Available online xxx

Keywords:
Carbon management
Green supply chain management
DEMATEL (Decision Making Trial and Evaluation Laboratory)
ANP (Analytical Network Process)
DANP (DEMATEL-based ANP)

ABSTRACT

The objective of this study is to introduce an evaluation system that allows firms to recognize the significant factors/criteria of carbon management and to develop strategies for carbon reduction. The evaluation criteria were developed from a literature review and consultations with practitioners in the electronics industry. We applied the Decision-Making Trial Evaluation Laboratory (DEMATEL) to construct the causal relationship among the evaluation system and the concepts of Analytic Network Process (ANP) to derive the influenced weights of criteria. This method can map out the structural relations among diverse factors in a complex system and identify the key factors for carbon management. The results indicate that carbon risk assessment is the most important criterion within the system, and manager commitment has the largest net influence degree viewed as the causal factor. Some management implications are provided in the discussion.

1. Introduction

How to build an effective management system for CO_2 reduction has become an important issue for a firm's survival in today's competitive environment. This study aims to develop a systemic decision making model that allows manufacturing firms to evaluate the effectiveness of their carbon management systems. With the increased awareness of climate change in the green supply chain, the World Business Council for Sustainable Development and the World Resources Institute (WRI, 2009) reported that at least 80% of carbon emissions are produced in the total supply chain (Hsu et al., 2013). Companies in different industries are well aware of the positive effects of CO_2 reduction management on operational performance in terms of cost savings, reputation building, and risk mitigation (Hart and Gautam, 1996; Theiben and Spinler, 2014). Due to government legislation and increasing awareness among the public to protect the environment, firms today cannot ignore environmental issues if they want to survive in the global market (Buyukozkan and Cifci, 2012). The 2010 supply chain report from the Carbon Disclosure Project (CDP) states that more than half of the members surveyed said that in the future, they would cease doing business with suppliers that do not manage their carbon emission wisely.

Given the growing environmental concerns in the past decade, a consensus is emerging that environmental pollution issues accompanying industrial development should be addressed along with green supply chain management (GSCM). Many efforts are currently being devoted to developing models and methods capable of analyzing carbon management. For example, Bai and Sarkis (2010) integrated a number of sustainable factors into a model of supplier selection that includes economic, environmental and social issues. Hsu et al. (2013) used Decision-Making Trial and Evaluation Laboratory (DEMATEL) to develop a supplier evaluation system for carbon management. Based on the causal diagram, they further provided some management implications to improve suppliers' performance. Considering the interdependency with suppliers, Theiben and Spinler (2014) use the Analytic Network Process (ANP) to evaluate which supplier is the most suitable partner for the implementation of CO_2 reduction management. As indicated from these studies, most prior studies (Theiben and Spinler, 2014; Hsu et al., 2013; Tseng and Chiu, 2013; Shaw et al., 2012; Chai et al., 2013; Bai and Sarkis, 2010) focus on the selection of appropriate suppliers for the implementation of a carbon management program. To the best of our knowledge, little of the literature discusses how to implement and improve an effective carbon management program within a firm using a systemic decision model. However, how to identify the critical success factors, such as organizational commitment, carbon policy, training and measures of carbon management, and how to build an effective evaluation system are important issues, as most firms fail because they are not

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http://dx.doi.org/10.1016/j.jclepro.2014.10.053
0959-6526/

well-organized. Hence, the existing supply chain management needs to be revised and extended by integrating CO_2 reduction related criteria that are directly influenced by the firm's carbon management characteristics as well as indirectly affected by suppliers' CO_2 management characteristics (Kim and Kumar, 2010).

This study fills this research gap by developing a cause-effect system that can indicate the essential ways to improve carbon management in a firm and incorporate an evaluation system for supplier selection. The development of a comprehensive evaluation model requires a decision model that is able to address many influencing factors, including various decision components, interactions among the components, trade-offs and cooperation with numerous supplier alternatives (Teng and Jaramillo, 2005). The applied model uses a graph-theory based DEMATAL method combined with the ANP concepts (called DEMATEL-based ANP, or DANP) to construct the interdependent relationships among the evaluation criteria (Huang et al., 2014; Chiu et al., 2013). The DEMATEL method is an effective way to use the knowledge of experienced experts to lay out the structural model of a system. It confirms the relationship among various perspectives, enhancing our understanding of complex systems and has been successfully applied in many situations, such as determining the factor critical to success, risk assessment, investment problem, service quality and supply chain management (Li et al., 2014; Ou Yang et al., 2013; Lee et al., 2011; Shieh et al., 2010; Ren et al., 2013). The complex relationships among GSCM systems can be illustrated with an influential network-relationship map (INRM), which, combined with the DANP, can help to measure the mutual importance of each critical factor in carbon management. Although the ANP is a powerful tool for deriving the weights of criteria for a network system, there is no systematic way to derive the network system itself. The advantages of the proposed method are that it can systematically construct a complex system using a graph-based method, identify the cause-and-effect relationships and derive the influenced weights of the factors within the system. Therefore, different from prior studies focusing on supplier selection for carbon management, this study contributes to the literature through its attempt to build a cause-and-effect system for supply chain and environmental management that can not only help firms identify the key factors but also provide the directions for improvement.

The remainder of this paper is organized as follows: In Section 2, a brief review of the existing literature is introduced. In Section 3, the DANP method is presented to construct the network-relationship and the importance of criteria. An empirical example using data from a Taiwanese electronics company is presented to demonstrate our proposed method in Section 4. Discussions are conducted in Section 5, and conclusions and remarks are presented in Section 6.

2. A brief review of the existing literature

Reviewing the literature on green or environmental supply chain management shows that a systematic evaluation model for a firm that wants to build an effective CO_2 reduction management is lacking. Most of the early literature may be limited to discussing the broad environmental criteria, either quantitative or qualitative, concerning environmental cost, production process, product, and management system for green supplier selection. Some typical studies relative to the carbon management or GSCM are illustrated below.

Noci (1997) could be the first study in the area of environmental-based supplier selection. He incorporated green competence, environmental efficiency, green image and life cycle cost into a vender rating system. Later on, Handfield et al. (2002) used the analytic hierarchy process (AHP) as a decision tool for supplier selection while adding the environmental dimension. Likewise, Humphreys et al. (2003) developed a knowledge-based system to evaluate supplier environmental performance that includes several environmental factors, such as environmental costs, green image, green design, environmental management system and environmental competencies. Wu et al. (2007) applied the AHP and fuzzy logic to help firms to measure suppliers' environmental performance and efficiency, but the AHP technique is not capable of handling interdependency among criteria. Considering hazardous substance management, Hsu and Hu (2009) utilized the ANP to construct an evaluation framework for supplier selection, which includes procurement management, research and development, process management, quality control and a management system. Tuzkaya et al. (2009) evaluated the environmental performance of suppliers with a hybrid fuzzy multi-attribute decision approach, which combined fuzzy ANP and a fuzzy Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) methodology. Awasthi et al. (2010) used fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) for evaluating the environmental performance of suppliers, and their criteria were the use of environmentally friendly technology, environmentally friendly materials, green market share, partnership with green organizations, management commitment to green practices, adherence to green policies, staff training, design for environment and pollution control initiative. In similar vein, Theiben and Spinler (2014) utilized the ANP to evaluate which supplier was the most suitable partner for the implementation of a collaborative CO_2 reduction management approach. Their study resides in the combination of literature and case-based decision criteria that aimed to enhance judgment validity with a particular emphasis on a collaborative setting.

Although the ANP method can handle the interdependency between criteria, the network relationship needs assumptions, which are mainly based on the authors' experience. Chang et al. (2011) utilized fuzzy DEMATEL to identify key influence criteria in selecting suppliers, which can help firms to forecast suppliers in terms of the observation of the influence of criteria. The structural relationships among criteria can be systematically constructed for supplier selection, and firms can obtain a clear understanding of the cause−effect relationship between criteria. Hsu et al. (2013) further applied the DEMATEL method to recognize the criteria for supplier selection and evaluation regarding carbon management competency in GSCM. The choice of the DEMATEL application comes from its ability to confirm interdependency among considered factors and its ability to derive a direct graph showing the interrelationships among factors (Lin et al., 2009). The importance of carbon management in other fields such as natural attraction, restaurant energy conservation and performance analysis of telecom centers, is also discussed (Horng et al., 2012; Hu et al., 2013; Hashemkhani Zolfani et al., 2012). This literature review indicates most prior studies focus on evaluating suppliers for the implementation of carbon management. The study on how to implement an effective carbon management program in a firm is lacking. Furthermore, although the ANP method incorporates the interdependency between criteria and improves the AHP method, the network structure is built on assumptions. In contrast with previous studies that discuss supplier selection, this study utilizes the DEMATEL-based ANP method (DANP) to explore the network relationship for the implementation of a carbon management program in a firm and the influenced weights of the criteria within the complex system. The method not only can systematically construct the network relationship but also can provide better direction for building an effective carbon reduction management.

Please cite this article in press as: Liou, J.J.H., Building an effective system for carbon reduction management, Journal of Cleaner Production (2014), http://dx.doi.org/10.1016/j.jclepro.2014.10.053