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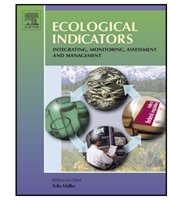

Effect of product recovery and sustainability enhancing indicators on the location selection of manufacturing facility

Kannan Govindan[a,*], Kiran Garg[b], Seema Gupta[b], P.C. Jha[b]

[a] Centre for Sustainable Operations Management, Department of Technology and Innovation University of Southern Denmark, Odense, Denmark
[b] Department of Operational Research, University of Delhi, Delhi, India

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ABSTRACT

The inclusion of economical, environmental, and societal issues in all stages of doing business helps to bring about sustainable development. A business begins or expands by establishing new facilities, so selecting a facility location is a strategic and crucial decision. In the context of sustainability, the selection of location for different facilities can be a critical problem, especially for manufacturing firms that endorse the wide footprint of Extended Producer Responsibility policies. This study aims at prioritizing alternative potential locations for manufacturing firms with respect to the three dimensions of sustainability identified above. The three dimensions are assessed by factors obtained through a factor analysis and are grouped by corresponding invariable sub criteria. These sub criteria are chosen from the extant literature review. Then, the preferred order of alternative potential location is obtained by Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) based on each location's overall performance. The performance of each alternative potential location is assessed on the basis of overall weights of alternatives, evaluating factors, and triple bottom line attributes, which were obtained by Analytical Hierarchical Process (AHP). The multi criteria decision making technique, AHP, calculates the weights of the qualitative and quantitative criteria impacting the location selection problem. Then the approach of the study is validated by applying a case from real life; the results are justified by completing a sensitivity analysis on the relative importance weights of the three primary attributes (economical, environmental, and social). The results of the sensitivity analysis demonstrate an effective decision making technique for the optimal selection of sustainable manufacturing locations.

1. Introduction

A major challenge of the modern supply chain is encompassing both ecological sustainability and humanitarian goals along with economic performance (Calder, 2013; Wua and Pagell, 2011). As Brundtland Commission, WCED (1987) mentioned, "*the environment does not exist as a sphere separate from human actions, ambitions, and needs. The* ***environment*** *is where we live; and* ***development*** *is what we all do in attempting to improve our lot within that domicile. The two are inseparable.*" Businesses can no longer ignore their responsibilities towards the impact of their supply chain on the environment, the community, and on the prevalence of end of life products. Business personnel, including customers, investors, stakeholders, regulators, and so forth are constantly evaluating companies on how they operate, use energy, treat their employees, manage production waste and handle product recovery under extended producer responsibility (EPR) policies. Consequently, the new barometer of a company's success is dictated by a quantification of their contributions towards the environment, the community, and on the use of public policies. Because of the preference for a sustainable organization, businesses need to include product recovery and the evaluation of sustainability criteria in every field of their enterprise. The inclusion of sustainability concepts in a company's existing supply chain (SSC) is an essential element to create long term values for shareholders. Further, appropriate sustainability concepts will help to reduce the company's ecological impacts and may generate new sources of revenue (Carter and Rogers, 2008). It is important to note that the strategic relevance between market and sources, demand and supply in the globalized supply chain requires coordinating and integrating all business operations with sustainable development issues (Büyüközkan and Berkol, 2011). Sustainable development is "*a process of achieving human development in an inclusive, connected, equitable, prudent and secure manner*" (Hart and Milstein, 2003).

To achieve the goals of sustainability, an organization needs to synchronize the complexities and variability among financial,

* Corresponding author. Tel.: +45 65503188.
E-mail address: kgov@iti.sdu.dk (K. Govindan).

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social, and environmental elements. The interface of these three elements is termed the triple bottom line (TBL) (Fauzi et al., 2010). Designing a SSC by simultaneously considering economical, environmental, and social criteria is a complex decision process and can easily lead to failure. Thus, the primary objective of a supply chain that excels is to include sustainability concepts and, ideally, to be cross-functional as well. Sustainable performance is dynamic; in a company, it can be implemented in one or more parts of the supply chain, and such performance may vary across contexts and time periods. Organizations seeking to implement sustainability measures in their supply chain must assess their strategic decisions with regard to TBL quantifiable elements and to their sub criteria. A supply chain begins with the determination of geographical location of facilities, a decision that has high degree of strategic importance because location involves long term commitments and it is a decision that is difficult to reverse. But the decision for location involves more than just a simple site selection. Technology availability, geopolitics and political regulations, and the requirements for a manufacturing firm's particular footprint make the decision more complicated. Further, when supply and demand bases become global, manufacturers are obligated to include take back of their used products and to account for their disposal. Clearly, location selection of facilities owned by manufacturing firms becomes a critical decision. A facility's location has great impacts on operating costs and revenues, the availability of qualified labour, competitive policies, access to raw material, and ease of product recovery (Tang and Zhou, 2012). Hence, the location of a manufacturing facility should move beyond more than cost effectiveness and the ease to reach customers and raw suppliers. The location decision should also consider easy access to skilled labour, information and product recovery process for end of life (EOL) and used products (Feldmann and Olhager, 2013). An effective manufacturing facility location decision needs to ensure all aspects and dimensions of facility sustainability through its location (Terouhid et al., 2012). The manufacturing process for the production of many goods in today's market requires lower production cost, easy access to highly skilled employees, prompt services to their customers, along with attractive return policies. It is vital for a manufacturing firm to integrate sustainability requirements in their decision making for facility location and to consider economical, environmental, and social issues.

The goal of this study is to assist manufacturing companies to identify preferred facility locations so sustainable practices, especially in the product recovery process, can be achieved (Govindan et al., 2015a). To accomplish this goal, we need to establish abroad-spectrum framework for measuring universal criteria of TBL elements. Taken as a whole, the rationale of the paper is to collect criteria from the three dimensions of sustainability and then rank their assessment with regard to a firm's facility location decision To develop a theoretical framework of sustainable development factors on a supply chain, we have chosen criteria from the existing literature with the rationale of evaluating and selecting the best manufacturing facility location from several potential feasible locations. Potential locations are identified based on their easy access to raw material, labour, and technology, and to being easily reachable by the customer. The framework of the study consists of the following steps. First, to blend chosen TBL criteria into effective measurable units, we use factor analysis to reduce the variability among criteria. Factor analysis reduces the number of criteria to be measured; it allows summative factors to interpret a set of criteria with less variability in view of decision makers. Then, due to the qualitative and quantitative nature of multiple factors in each of the three dimensions, and due to the subjective and empirical judgments made with regard to manufacturing facility location, we used multi criteria decision making techniques. To concentrate on sustainability requirements of supply chain design and their mapping in the selection of manufacturing facility location, we employed an integrated approach of both Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). These methodologies are combined in order to find the preference order of available locations. With the help of TOPSIS, the AHP methodology determines the weights of criteria which were used in determining the rank of the alternative locations. Next, to validate this approach, we provide a case study along with a sensitivity analysis. The study is categorized as follows. Section 2 discusses the existing literature relevant to the topic in order to come with the novelty of the study. Section 3 describes the problem and the method of its assessment. The problem assessment consists of identifying sustainability criteria and alternatives for choosing a manufacturing facility location. Section 4 discusses the research solution methodology used to achieve the aim of study. Section 5 validates our approach using a case study based on a manufacturer. Section 6 discusses the managerial implication of the results obtained, along with a sensitivity analysis. Section 7 concludes the study and considers its future scope.

2. Literature review

Complexities in network design, due to the interdependence among three dimensions of sustainable development, are advocated practically and academically. Tang and Zhou (2012) reviewed recent research done in the field of operations management related to sustainable business activities. They said there is a need to characterize financial, resource and community development flows of supply chains in order to respect the earth's ecosystems and to promote sustainability. Brandenburg et al. (2014) presented a systematic and methodological review of modelling approaches in sustainable supply chains adopted by authors. He reached the conclusion that only one out of nine papers on sustainable supply chain propose formal modelling, while the rest use conceptual analysis. Researchers have also realized that the focus of past research in the context of sustainability lies only in forward supply chains. A number of research articles on reverse logistics (Das and Chowdhury, 2012; Dat et al., 2012; Chaabane et al., 2012; Govindan et al., 2015d) and closed loop logistics (Amin and Zhang, 2012a,b; Özceylan and Paksoy, 2013) complement sustainability in product life cycles. For years, the majority of articles considered only the environmental impact of a supply chain network as a measure of sustainability (Chaabane et al., 2012; Kannan et al., 2012; Pishvaee et al., 2012b; Ramudhin et al., 2010). To embark upon the environmental issues in network design, researchers used multi objective mathematical programming. Then, with the emphasis on TBL reporting as the measure of sustainability performance, literature that simultaneously considered social issues and supply chain network design started to gain the interest of academicians. Initially, corporate social responsibilities and related necessary factors were explored in standalone fashion (Mitra, 2011; Cruz, 2009; Ciliberti et al., 2008; Hsueh, 2014). Farzad and Mansour (2009) proposed to design a sustainable recovery network with the help of multi objective mathematical modelling to, at best, achieve economical and societal goals, and at the minimum, to reduce environmental impacts. They considered the impacts of processing and shipping as environmental issues, while local development, employment, and damage were considered as social issues. Dou and Sarkis (2010) considered various environmental and social factors of sustainability to evaluate and select various off-shoring alternatives. Planning and designing of a supply chain that took social responsibilities in uncertain environment into account was considered by Pishvaee et al. (2012a), who minimized the cost of operating the supply chain and maximized the social responsiveness. The criteria under social responsibilities studied by Pishavee were hazardous products;