Expert Systems with Applications 38 (2011) 13731–13748

Contents lists available at ScienceDirect

Expert Systems with Applications

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

Designing a sustainable supply chain using an integrated analytic network process and goal programming approach in quality function deployment

Gülçin Büyüközkan *, Çiğdem Berkol

Galatasaray University, Industrial Engineering Department, Çırağan Caddesi No: 36 Ortaköy, Istanbul 34357, Turkey

ARTICLE INFO

Keywords:
Sustainable supply chain
Analytic network process
Zero one goal programming
Quality function deployment

ABSTRACT

Sustainable supply chain management (SSCM) provides economic, social end environmental requirements in material and service flows occurring between suppliers, manufacturers and customers. SSCM structure is considered as a prerequisite for a sustainable success. Thus designing an effective SCM structure provides competitive advantages for the companies. In order to achieve an effective design of this structure, it is possible to apply quality function deployment (QFD) approach which is successfully applied as an effective product and system development tool. This study presents a decision framework where analytic network process (ANP) integrated QFD and zero-one goal programming (ZOGP) models are used in order to determine the design requirements which are more effective in achieving a sustainable supply chain (SSC). The first phase of the QFD is the house of quality (HOQ) which transforms customer requirements into product design requirements. In this study, after determining the sustainability requirements named customer requirements (CRs) and design requirements (DRs) of a SSC, ANP is employed to determine the importance levels in the HOQ considering the interrelationships among the DRs and CRs. Furthermore ZOGP approach is used to take into account different objectives of the problem. The proposed method is applied through a case study and obtained results are discussed.

1. Introduction

For some years companies and environmental authorities have been increasing their awareness in incorporating environmental issues into their respective systems. Terms such as environmental design, sustainable design, environmentally-conscious processes or products, clean technologies, and green products or systems are now becoming widely important (Halog, Schultmann, & Rentz, 2001). As the environmental consciousness has become a fundamental design focus for both production and service systems, supply chains that combine manufacturing and service systems gained importance in environmental area. Recently, the first objective of a supply chain was to manage the "better quality-low cost" paradox and other requirements of stakeholders. However as an effect of the globalization quality and cost are no longer considered as competitive differences in supply chain management (SCM). Sustainable supply chain (SSC) on the other hand provides competitive advantages to the companies as it offers the opportunity to differentiate from other companies by being equitable in the fair utilization of natural resources, prudent enough not to harm the environment, being socially responsible in terms of equal human development, ensuring health and safety of employees and contributing to humanity and the environment.

Nowadays, it is not easy to achieve sustainability in a supply chain without considering budget limitations or the fact that a project may not be efficient or enough to achieve sustainability. To achieve sustainability effectively it is necessary to achieve improvements in economic, social and environmental area. Any project should take into account these three aspects of the sustainability and the investment cost. Designing a sustainable supply chain is a critical process which can lead a total failure when the time comes to apply. In addition to this any application in a particular point of a supply chain affects instantly the entire supply chain. That is why in order to decide what steps to take for a sustainable supply chain design; some decision methods must be used. Quality function deployment (QFD) as a well known method has a large application area within the sustainability framework, such as sustainable product development, improvement analysis and design process. In this study in order to design effectively a sustainable supply chain, QFD approach is used as it is a commonly used tool for environmentally conscious design process. Some of those studies in the literature are Madu, Kuei, and Madu (2002), Sakao (2007), Kuo, Wub, and Shieh (2009). The first phase of the QFD is the house of quality (HOQ) which is the key strategic tool to determine the DRs that satisfy the CRs. Determining the relative importance of customer requirements (CRs) and design requirements (DRs) is an important step of the QFD. In order to determine their relative importance several methods are applied by many authors. Analytic hierarchy process (AHP), fuzzy set theory and

* Corresponding author. Tel.: +90 212 227 4480.
E-mail address: gulcin.buyukozkan@gmail.com (G. Büyüközkan).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.04.171

analytic network process (ANP) are the frequently used methods. AHP combined QFD methodologies are used by many authors such as Lu, Madu, Kuei, and Winokur (1994), Madu and Kuei (1994), Madu, Kuei, Aheto, and Winokur (1994b), Park and Kim (1998), Wang, Xie, and Goh (1998), Lam and Zhao (1998), Koksal and Eğitman (1998), Zakarian and Kusiak (1999), Partovi and Epperly (1999), Partovi (1999), Chuang (2001), Partovi and Corredoira (2002), Partovi (2001), Hsiao (2002), Kwong and Bai (2002, 2003), Madu et al. (2002), Myint (2003), Bhattacharya, Sarkar, and Mukherjee (2005), Hanumaiah and Mukherjee (2006), Partovi (2007), Presley, Meade, and Sarkis (2007), Çelik, Cebi, Kahraman, and Er (2009), and Georgiou, Gotzamani, Andronikidis, and Paltayian (2008). On the other hand as AHP includes an assumption about the independence among elements under a hierarchical structure, it does not consider the possible interrelationships among DRs and CRs. Thus the ANP method which takes into account the interrelationships among DRs and CRs is used in this study in order to obtain a well-built model as in many other studies like Karsak, Sozer, and Alptekin (2002), Partovi (2001), Lin, Cheng, Tseng, and Tsai (2010), Partovi and Corredoira (2002), Kahraman, Ertay, and Büyüközkan (2006), Iranmanesh and Tabrizi (2009), Lee, Wu, and Tzeng (2008), Andronikidis, Georgiou, Gotzamani, and Kamvysi (2009), Alptekin and Isiklar (2005), Pal, Ravı, and Bhargava (2007), Georgiou et al. (2008), and Büyüközkan, Ertay, Kahraman, and Ruan (2004). In this paper, the methodology proposed integrates two decision making techniques, ANP and zero one goal programming (ZOGP) for determining the DRs that will be considered in designing the sustainable supply chain. The ZOGP is used in order to determine the DRs to be considered in the design process satisfying the ANP results and the goal named "cost" in this study.

zzzzThe plan of the article is as follows. In Section 2, definition of the sustainability concept and its appearance in supply chain is given. Section 3 announces the application areas of QFD in general and then presents literature survey of the sustainable QFD. Section 4 presents literature surveys of ANP combined QFD and integrated ANP&ZOGP combined QFD approaches. And then the decision methodology is given. In Section 5, the proposed QFD based sustainable SCM framework is presented. Finally in Section 6 the decision framework is illustrated via a case study.

2. Sustainability in supply chain

2.1. The concept of the sustainability

Earth as a resource system has a limited capacity for supporting a growing human population with an intensive exchange of materials and energy with its environment (Tsoulfas & Pappis, 2006). Due to the media and academia, the potential long-term implications of overusing these resources are known better. In recent years, interest in environment preservation is increasing, and emerging as real business targets (Feretti, Zanoni, Zavanella, & Diana, 2007). As a result, many countries have started to enforce environmental legislations and regulations for controlling the use of products, processes and wastes that may be detrimental to the environment (Lee, Kang, Hsu, & Hung, 2009). The European Parliament views this concept of sustainability as so critical to the future of the EU that current and future legislation must integrate sustainability into implementation orders. Considering the earlier influence of the EU in the area of quality management and the global adoption of ISO 9001 certification, the influence of the EU about the sustainability can be estimated.

At this point sustainability, generally defined as "using resources to meet the needs of the present without compromising the ability of future generations to meet their own" (Linton, Klassen, & Jayaraman, 2007), is acquiring importance for the public and for industry. Until 10 years ago, the unique aim of business was to achieve the maximum economic profit or to improve the customer service but now environmental topics play a very important role, becoming a central point of the strategic and operative management policies (Feretti et al., 2007). There is a great awareness of sustainability and environmental responsibility in academia and business. The top global companies (Exxon Mobil, General Electric, Royal Dutch/Shell, Daimler Chrysler, Toyota Motor, Hitachi, Sony, etc.) put headings such as "Sustainability and Environment," "Environmental Initiatives," "Environmental Activities," or "Environmental Leadership" on the front pages of their websites and in recent years we have witnessed an abundance of calls for papers that bridge operations and environmental issues (De Brito & Van Der Laan, 2008). Lately the number of companies who think that sustainability and profitability are not mutually exclusive concepts is increasing. Their common perspective is that the sustainability creates longterm shareholder value as it is an obligation for companies to meet the needs of their shareholders while sustaining the resources that will be needed in the future. The scarcity of raw materials such as fossil fuels and water, new regulations of governments and the global awareness about sustainability leads companies to develop sustainable strategies. These companies use various strategies and tools to assess their economic, social and environmental impacts associated with sustainability, such as environmental management systems, pollution prevention, waste minimization, design for environment and clean technology programs.

2.2. Sustainability in supply chain

As the connection between markets and sources, demand and supply has increased the strategic relevance of SCM, in today's competitive world maintaining an efficient and flexible supply chain became critical for every enterprise. With the increasing acceptance of ISO 14001 environmental standards, there is a greater role for supply chain management in organizational environmental practice (Sarkis, 2003). In order to retain and strengthen their competitive edge in the market, organizations need to coordinate and integrate all their business operations with sustainability considerations. A focus on supply chain is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer. However, sustainability also must integrate issues and flows that extend beyond the core of supply chain management: product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life (Linton et al., 2007). Sustainability involves the multiple objectives of social, economic and environmental sustainability. For social sustainability, products should ensure that the needs of population are met. For economic sustainability, the goal of supply chain optimization and scheduling is maximizing the profits, i.e. maximizing products values with minimum raw materials, inventory and production costs. For resources sustainability, as for environmental sustainability, non-renewable resources consumption should be minimized, the resource use should be efficient to minimize wastes generated and permanent environmental damage should not be allowed (Zhou, Cheng, & Hua, 2000). Integrating sustainability into the supply chain has several advantages. A SSCM reduces waste created and thereby realizes cost savings through the entire supply chain while increasing the revenue and the market share as the preference for sustainable organizations increases. In addition to this, sustainability helps to hire talented employees who pay attention to the organization's environmental behavior. On the other hand, it also increases the employee