



A green supplier selection model for high-tech industry

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ABSTRACT

With growing worldwide awareness of environmental protection, green production has become an important issue for almost every manufacturer and will determine the sustainability of a manufacturer in the long term. A performance evaluation system for green suppliers thus is necessary to determine the suitability of suppliers to cooperate with the firm. While the works on the evaluation and/or selection of suppliers are abundant, those that concern environmental issues are rather limited. Therefore, in this study, a model for evaluating green suppliers is proposed. The Delphi method is applied first to differentiate the criteria for evaluating traditional suppliers and green suppliers. A hierarchy is constructed next to help evaluate the importance of the selected criteria and the performance of green suppliers. Since experts may not identify the importance of factors clearly, the results of questionnaires may be biased. To consider the vagueness of experts' opinions, the fuzzy extended analytic hierarchy process is exploited. With the proposed model, manufacturers can have a better understanding of the capabilities that a green supplier must possess and can evaluate and select the most suitable green supplier for cooperation.

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1. Introduction

With increasing government regulation and stronger public awareness in environmental protection, firms today simply cannot ignore environmental issues if they want to survive in the global market. In addition to complying with the environmental regulations for selling products in certain countries, firms need to implement strategies to voluntarily reduce the environmental impacts of their products. The integration of environment, economic and social performances to achieve sustainable development is a major business challenge for the new century (Verghese & Lewis, 2007).

Environmental management is becoming more and more important for corporations as the emphasis on the environmental protection by organizational stakeholders, including stockholders, governments, customers, employees, competitors and communities, keeps increasing. Programs such as design for the environment, life cycle analysis, total quality environmental management, green supply chain management and ISO 14000 standards are popular for environmentally conscious practices (Sarkis, 1998). Both proactive and reactive methods have been implemented to protect the environment. For instance, environmentally conscious design and man-

ufacturing (ECD&M) is a proactive method that aims to reduce the resource consumption, hazardous emission and energy usage by reengineering the design and manufacturing process and selecting appropriate materials (Zhang, 2004). On the other hand, end-of-life (EoL) strategy and management is a reactive method that provides technology and methodologies to handle the wastes which are already present (Zhang, 2004).

As environmental awareness increases, buyers today are learning to purchase goods and services from suppliers that can provide them with low cost, high quality, short lead time, and at the same time, with environmental responsibility. Legislative and regulatory initiatives have also emerged in developed countries, especially in Europe and Japan. Some pioneer enterprises have already joined the trend of green supply chain long before the EU environmental orders were enforced. In order to have a long-term success in the global market, a firm not only should stress on financial terms in evaluating suppliers, but also should take various criteria, including pro-environmental concerns, into consideration. Therefore, green procurement approach must be compliant with customers, laws and regulations, and a green supplier evaluation system is necessary for a firm in determining the suitability of a supplier as a partner in the green supply chain.

The rest of this paper is organized as follows. Section 2 reviews some recent works on environmental management and green supplier evaluation. Analytic hierarchy process (AHP), fuzzy set theory and fuzzy-extended AHP (FAHP) are presented in Section

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3. Section 4 proposes a FAHP model applied to evaluate green suppliers. Some concluding remarks are made in the last section.

2. Environmental management and green supplier evaluation

2.1. Environmental management

People are increasingly aware of the strong links between the economy and the environment these days. Exploiting the synergies between the two is essential to maximize both well-being and economic growth. 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. For instance, EU has set a range of environmental policies such as RoHS and WEEE. The RoHS Directive (the restriction of the use of certain hazardous substances in electrical and electronic equipment) bans manufacturers, sellers, distributors and recyclers of electrical and electronic equipment (EEE) the placing on the EU market of new electrical and electronic equipment containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants (RoHS, 2008). The RoHS Directive came into force on 1 July 2006. The WEEE (waste electronics and electrical equipment) Directive aims to reduce waste arising from electrical and electronic equipment (EEE), decrease the wastes of natural resources, prevent pollutions from occurring, and make manufacturers, sellers, distributors and recyclers of EEE responsible for the environmental impact of their products (Netregs, 2008). The WEEE Regulations came into force on 1 January 2007 with the main requirements and obligations on producers and distributors of EEE into force from 1 April 2007 (Netregs, 2008). WEEE is aimed at the life cycle of product, and RoHS is exploited during the design stage of products. While there are environmental regulations and mandatory programs, pressures to protect the environment also come from other external stakeholders. Thus, many firms are introducing voluntary environmental programs for gaining competitive advantages. Indeed, environmental management is becoming the focus of corporate strategy and an arena of competition, rather than simply as a compliance-driven function (Sarkis, 1995). Sarkis (1998) categorized environmentally conscious business practices into five major components: design for the environment, life cycle analysis, total quality environmental management, green supply chain and ISO 14000 environmental management system requirements.

In order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain. Green supply chain management has emerged as a way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency (van Hock & Erasmus, 2000). The definition of green supply chain management ranges from simple green purchasing to an integrated supply chain flowing from supplier, manufacturer, customer, and to reverse logistics (Zhu & Sarkis, 2004). Working on reducing product life cycle impact in saving energy, saving resources and eliminating hazardous substances are important issues for all members in the supply chain. In fact, one effective way to facilitate environmental protection is to focus on waste prevention and control at the source through green purchasing (Min & Galle, 1997). That is, firms must include suppliers in environmentally-friendly practices for purchasing and materials management, starting even from suppliers' design for environment (DfE). Green purchasing, or green procurement, is linked to the product and process aspects of the supplier, including "eco-labels, the avoidance of environmentally relevant substances, energy use, use of recycled materials, product mass, re-usability of some parts, recyclability, the use of

environmental management systems and the application of DfE or life cycle assessment (LCA)" (Nagel, 2003). A green supplier is expected not only to achieve environmental compliance but also to undertake efficient, green product design and life cycle analysis activities. Thus, in a green supply chain, companies need to have extensive supplier selection and performance evaluation processes (Kainuma & Tawara, 2006).

Manufacturers and exporters these days need to overcome the green obstacle to increase competition power (Deng & Wang, 1998). For instance, EU forces importers to follow the environmental policies, change their working processes, and purchase more environmental-friendly equipment and costly green materials. With the enforcement of environmental regulations and arising eco-awareness, manufacturers need to find substitutes to replace the detrimental substances if they want to export their products to environmental-conscious countries. Since many Taiwanese businesses are OEM (original equipment manufacturing) and ODM (own design manufacturing), in order to export their products overseas, the firms not only need to comply with the environmental policies, but also need to have their own corporate environmental policies.

The LCD industry in Taiwan has expanded tremendously in the past ten years. Taiwan is currently the world's largest supplier of TFT-LCDs, and produces more than 40% of the world's supply (Hung, 2006). By 2005, there were 123 companies in Taiwan's flat-panel display industry, creating a value of US\$15.49 billion, of which TFT-LCDs accounted for around 66% (Government Information Office (GIO). Taiwan yearbook, 2005). However, in order to maintain the competitiveness, manufacturers in the TFT-LCD supply chain not only need to adapt to the increasing demands, scale of economies and lower price, they also need to comply with the environmental regulations of the countries they export the products to. On top of that, a higher green standard than the baseline of the regulations may even need to be met by the manufacturers in order to maintain a good relationship with existing customers and to attract new international customers.

2.2. Green supplier evaluation

In the current business environment, purchasing has become critical in establishing value-added contents of products and a vital determinant to ensure the profitability and survival of a company. The research on supplier selection is abundant. First publications can be traced back to the 1960s, and Weber, Current, and Benton (1991) and Ghodsypour and O'Brien (1998) did a comprehensive review on the past research. Some popular methods include the categorical method, the weighted-point method, the matrix method, the vendor profile analysis, and the ANP approach, to name a few (Noci, 1997). Recent works were reviewed in Kahraman, Cebeci, and Ulukan (2003), Lin and Chen (2004), Bayazit (2006), Talluri, Narasimhan, and Nair (2006), and Lee (2009). While literature related to supplier evaluation is plentiful, the works on green supplier evaluation or supplier evaluation that consider environmental factors are rather limited (Handfield, Steven, Srouft, & Melnyk, 2002; Humphreys, McIvor, & Chan, 2003b; Humphreys, Wong, & Chan, 2003a; Noci, 1997).

The purchasing process becomes more complicated when environmental issues are considered. This is because green purchasing must consider the supplier's environmental responsibility, in addition to the traditional factors such as the supplier's costs, quality, lead-time and flexibility. The management of suppliers based on strict environmental compliance is not sufficient, and a more proactive or strategic approach is required. Noci (1997) designed a green vendor rating system for the assessment of a supplier's environmental performance based on four environmental categories, namely, 'green' competencies, current environmental efficiency, suppliers' 'green' image and net life cycle cost, by applying AHP.

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