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Using QFD and ANP to analyze the environmental production requirements in linguistic preferences

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ABSTRACT

This study is to apply fuzzy quality function deployment (QFD) model with interdependence relations of environmental production requirements (EPRs) aspects and sustainable production indicators (SPIs) criteria for original equipment manufacturing (OEM) firm in Taiwan. At first, to facilitate the main issue of the QFD problem, however, the "Whats" question of EPRs and "Hows" problem of the SPIs have to be made, which are two major components and be emphasized on the house of quality matrices. In conjunction with fuzzy sets theory and analytical network process, the systematic analytical procedures are proposed. Subsequently, a case study demonstrated the evaluation process for identifying "Whats" and "Hows". The results of empirical study show that (1) five aspects of EPRs are deemed to have priority to improve the environmental practice; and (2) twenty-two feasible SPIs criteria are practical indicated. In addition, it is suggested that case firm should aware attentively the SPIs and emphasize on exploiting these EPRs effectively. And develop the "Hows" issues, which should continuously strengthen of the EPRs, respectively.

1. Introduction

Leading environmental management issues emphasize the need to understand manufacturing decisions and practices for an original equipment manufacturing (OEM) firm to improve its production process in Taiwan. Various studies argue that manufacturing decisions and choices have to be consistent with the corporate strategy for effective environmental production management (Tseng, Lin, Chiu, & Liao, 2008a, 2008b; Tseng & Lin, 2008). The environmental management has become the most concern of manufacturing firms, which seek for higher levels of green product quality and continuous improvement to keep up with the change throughout the world. However, the environmental practices are dependent on wider aspects to be integrated in order to achieve firm's goal of waste elimination and lower environmental impact. Hence, firms must integrate environmental aspects to ensure corporate survival and toward sustainable development.

A number of studies have explored how to evaluate the environmental production requirements (EPRs) in life cycle assessment (Veleva & Ellenbecker, 2001; Veleva, Hart, Greiner, & Crumbley, 2001). None efforts, have been focused on establishing EPRs evaluation framework for OEM firms, because most OEM firms are based on ISO 14000 manual to reduce the impact of environment (Balzarova & Castka, 2008; Nishitani, 2009; Tsai & Chou, 2009). However, to differentiate from the ISO 14000, this study follows the nature of operations process of OEM firm urges the necessary to justify the EPRs evaluation aspects and criteria. Therefore, an effective and structured EPRs aspects and criteria for OEM firms need to be developed. A challenge of this approach is that EPRs evaluation is always in uncertainty due to environment information are rapidly changes and the aspects are measured in linguistic terms. In many practical cases, the human preference model is uncertain and might be reluctant or unable to assign exact numerical values to describe the preferences. As this result more desirable for the researchers to use fuzzy set theory evaluation.

The OEM firms are aim the satisfaction of the customer at the very beginning, namely the product design phase, the approach evaluation bases on total quality management, which offers a vast techniques to ensure the improvement of quality and productivity. Especially, quality function deployment (QFD) is one of these techniques to design the needs of customer and into practical measures. This approach enables the firms to become proactive to quality problems rather than taking a reactive position by acting on customer complaints. In addition, QFD is applied to plan and design new or improved products or services. It employs a cross-functional team to determine customer needs and translate them into product designs through a structured and well-documented

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framework. This systematic nature evaluates the necessary decisions for change and development at the beginning of the design process, reducing and avoiding the project changes and corrections. Hence, in real situation, numerous criteria are interdependence when evaluating an OEM firm in EPRs.

As a typical study to understand the interdependence relations, for instance, a firm that has outstanding energy and material for natural environment to performance in controlling the waste elimination and hazardous for natural environment such as controlling process for producing and improving green products. The analytical network process (ANP) is most suitable tool for solving interdependence relations among the criteria and attributes (Saaty, 1996). The merits of ANP are as follows: (i) both tangibles and intangibles, individual values, and shared values can be included in the decision process; (ii) the discussion can be structured so that every criteria relevant to the decision is considered; and (iii) in a structured analysis, the discussion continues until relevant information from each individual member in the group is considered and a consensus is achieved. In addition to these merits of ANP provides a more generalized model in decision-making without making assumptions about the independence of the aspects and criteria (Dyer & Forman, 1992).

The aim of this study was to get a better understanding of a particular, strategic operating decision area in improvement of production process toward sustainability. This study attempts to develop a EPRs hierarchical framework that is sufficiently general that it can be applied. To date, few studies have adopted such a rigorous methodology. This study presents a combined of fuzzy set theory, ANP and QFD that is sufficiently general and it can be applied under various study settings. This firm evaluation in this EPRs assessment can help firms to develop the measures of optimal sustainable production indicators (SPIs). Consequently, resolving problems in evaluating firm is fundamentally important to both researchers and practitioners. The unique point of this study is involved in qualitative measures in linguistic terms presented by triangular fuzzy numbers (TFNs) and defuzzified into a crisp value for analyze in interdependence relations among aspects and criteria, and apply ANP and QFD to acquire the optimal decision-making.

This study begins with a brief introduction of the EPRs and the study objectives. Section 2 follows a literature discussion of the EPRs and SPIs and related literatures. Section 3 presents the proposed method. Section 4 presents the empirical study case. A study framework suggests providing a context for applied the proposed method. Section 5 concludes with a summary of the study finding of the method as well as recommendations for its further development and practical application.

2. Literature review

Due to the increased green competitive pressures are also forcing firms to continuously develop to enhance production competitiveness for OEM firms. For this reason, a firm must develop and evaluate the EPRs more rapidly than other firms, and must facilitate SPIs within its organization to strengthen its green competitive advantage. Lowell Center for Sustainable Production (LCSP) (1998) defined sustainable production as the creation of goods and services using processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people. This definition is consistent with current understanding of sustainable development, since it emphasizes environmental, social and economic aspects of firms' activities. Only recently have a growing number of firms begun to use environmental, health and safety, and social indicators (Tseng, 2009; Tseng & Lin, 2008).

Based on differing EPRs perspectives, some studies have presented the indicators or constrains for the sustainable production measures. Existing business-related sustainability indicators tend to emphasize the environmental aspects of production. However, Veleva et al. (2001) argue that SPIs should include not only production measures but also measures of the economic and social. Therefore, they proposed a framework that consists of five levels for categorizing existing indicators relative to the basic principles of sustainability. The study purpose provided a method to evaluate a set of indicators focusing on environmental, health and safety aspects of production and work is underway to expand it to include social and economic aspects, to inform decision-making and measure progress toward more sustainable production. Veleva and Ellenbecker (2001) presented a set of indicators of sustainable production for promoting business sustainability. It first introduces the concept of sustainable production as defined by the LCSP, including six dimensions and desirable qualities. Based on the framework, the study suggests five stages of core and supplemental indicators for raising firms' awareness and measuring their progress toward sustainable production systems. The six dimension: (1) energy and material use; (2) natural environment; (3) economic performance; (4) community development and social justice; (5) workers, and (6) products. Rădulescu, Rădulescu and Rădulescu (2009) formulate and study a multi-objective approach for production processes, which implements suitable constraints on pollutant emissions with considered two alternative optimization problems. In addition, Su, Chiueh, Hung and Ma (2007) studied many modern decision-making support systems which already partially consider social factor analysis in addition to expenses and benefits, environmental effects, technical issues, and management aspects. In conclusion, the SPIs of a firm bases on multiple aspects and criteria approach with qualitative measures. Morrissey and Browne (2004) proposed that a sustainable management model should not be only environmentally effective and economically affordable but also socially acceptable. Therefore, overhauling production process to achieve firm's goal of waste elimination and reduce the impacts of EPRs are necessary for composing a set of SPIs.

Based on literature findings, activities, processes and characteristics associated with SPIs applications are adopted as SPIs dimensions. Fresner (1998) resulted on Austrian Preventive environmental protection approaches in Europe project that the process water could be saved by reusing cooling water as process water: (1) water usage could be avoided by optimizing the use of water through better process control. (2) Operational sequences have been changed to avoid waste. (3) The operators were trained to calculate the exact demand of chemicals to avoid bath rests. (4) Wasted dyeing baths are reused. De Bruijn and Hofman (2000) analyzed the contribution of pollution prevention to the transformation of industry by evaluating the results of various pollution prevention projects. As Resulted that pollution prevention has proven to be a valuable concept, because prime focus on material flows and the emphasis on minimization of environmental effects. It leads to improvements in efficiency and reductions in waste and emissions. The product orientation is undervalued in pollution prevention. Pollution prevention can be an important path of companies towards a more sustainability-based strategy. Shriberg (2002) described "..... The Michigan housing sustainability study was development thirty-eight recommendations to move the organization toward sustainability and assessed in terms of their importance, cost and implementation time to produce priority". Grutter and Egler (2004) have described cleaner production is a preventative integrated continuous strategy for modifying products, processes or services, has been considered as the best technological strategy and good housekeeping toward sustainable development. Kjaerheim (2004) showed that the description of success cleaner production can give often both environmental