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Environmental performance evaluation of implementing EMS (ISO 14001) in the coating industry: case study of a Shanghai coating firm

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ABSTRACT

The implementation of an Environmental Management System (EMS) ISO 14001 is an instrument for achieving a corporate's sustainable development and therefore is an important tool for environmental management. Due to rapid economic development, the coating industry is increasing rapidly, resulting in several environmental problems. Many coating firms have adopted EMS; however, quantitative and qualitative evaluations of the environmental performance of EMS have rarely been examined in the literature. This paper proposed an environmental performance evaluation system that enables quantitatively assess the effects of EMS in the coating industry. A four-level framework was structured with 74 indicators and sub-indicators according to the context and characteristics of the coating industry. Divided into two aspects, the legislative system and environmental management performance system, these indicators and sub-indicators covered almost every element of ISO 14001. And the evaluation criteria were closely referred to Chinese coating industry standards and cleaner production regulations. Using analytical hierarchy process and fuzzy membership degree analysis, the weight of each indicator was determined, and evaluation results were achieved. Moreover, using a coating firm in Shanghai as a case study, this paper investigated the impacts of EMS implementation in two successive years after the firm was granted an ISO14001 certificate in 2007. The results indicated that the environmental performance of EMS in the coating firm was satisfactory in 2008, and there was an obvious improvement in 2009, which strongly demonstrated that the evaluation model was scientific and practical. Finally, further improvements are proposed from four aspects, including thoroughly identifying environmental factors, encouraging the development of advanced pollution control technologies, sustaining the improvement process of EMS after the initial adoption, and supporting the involvement of software applications.

1. Introduction

The coating industry has undergone great changes due to rapid industrialization and urbanization over the past several decades. In 2010, the global market scale of coatings reached approximately about 90 billion dollars and was expected to grow by approximately 10% in 2011 (GCCIR, 2011). Geographically, China leads the world in terms of infrastructure and real estate investment; therefore, there is no doubt that China is the world's largest coating market. In 2011, the market scale of coating in China was approximately 18.9 billion dollars, 54% of which was attributed to decorative coatings (GCCIR, 2011). However, the coating industry is also one of the most polluted industries in China. Pollution by organic toxicants, especially volatile organic compounds (VOCs), results in tremendous environmental impacts on human health and has largely hindered the sustainable development of China (Klimont et al., 2002; Yuan and Yu, 2009). The coating industry thus urgently needs more effective environmental management.

An environmental management system (EMS) is a systematic process designed to manage the environmental impacts of a business and reduce the environmental risk associated with business activities (Seymour and Ridley, 2005; Cary and Roberts, 2011). In 1996, the International Organization for Standardization (ISO) adopted a new international standard for EMS, ISO 14001, which provides the criteria for an environmental management system. Despite being a voluntary standard, its adoption may lead enterprises to improve the control and management of their process, products and services. It also helps to reduce costs and increase profits over the medium and long term (Epstain and Roy, 1997). Hence, adoption of EMS (ISO14001) has constituted one of the most important elements of corporate sustainability around the world within different industries, such as mining, paper, chemical,

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construction and automotive industry (Barla, 2007; Comoglio and Botta, 2012; Gavronskia et al., 2008; Newbold, 2006; Rodríguez et al., 2011). The Chinese government has been strongly promoting the implementation of ISO 14001. In 2006, at least 18,979 organizations had obtained ISO 14001 certificates in China (ISO World, 2006). Importantly, the EMS ISO14001 standards are not performance standards but a continuous process. In other words, these standards do not mandate a firm's environmental performance level, instead describing a system to help a firm achieve its own environmental objectives (Melnyk et al., 2003). This situation generates the following questions: How does the presence of a formal EMS affect a coating firm's operational and environmental performance? Does a coating firm benefit from having a formal, certified environmental management system? The effectiveness of EMS must be evaluated scientifically. Little systematic research has been devoted to evaluating the performance of EMS implementation in small and medium-sized coating firms, and no accredited method or model exists to conduct such an evaluation. The aims of this study are therefore two-fold:

(1) A system of indicators that is ideal for the coating industry is developed, and a detailed evaluation of the environmental performance for a coating firm with ISO 14001 is presented in this paper.
(2) Using such an approach, it is possible for decision-makers to evaluate both the actual and the potential environmental performance of EMS implementation in the coating industry.

This paper is organized into five major sections: Section 1 introduces the background of EMS, the coating industry and the major objectives of our study. Section 2 lays the groundwork for developing the evaluation model, while Section 3 develops the framework of the evaluation method and identifies the indicators and weights. Section 4 applies the evaluation framework to a coating firm, and presents the major findings and discussions. To conclude, Section 5 suggests directions for future research.

2. Methodology

2.1. ISO 14001 and environmental performance

The relationship between EMS (ISO 14001) and environmental performances is subject to increasing interest by international researchers (Ammenberg et al., 2002; Nawrocka and Parker, 2009; Perotto et al., 2008). Based on the principles of PDCA (Plan, Do, Check, and Act), an ISO 14001 certified EMS must be established and operated using five main aspects: environmental policy, planning, implementation and operation, checking and corrective action, and management review (Nishitani, 2009). Therefore, critical factors assessing the environmental performance of an EMS should cover all the five elements. In our study, the qualitative and quantitative indicators were chosen through: (i) respecting all applicable environmental regulations for the coating industry; (ii) documenting and analyzing all the environmental impacts according to the coating industry's typical pollutants; (iii) systematic checklist-type procedure towards preventing and reducing pollution, such as worker training programs and communication procedures; (iv) corrective procedures designed to deal with cases of non-conformity; (v) review of both employees and employers to ensure continuous improvement of EMS operations.

2.2. Fuzzy comprehensive evaluation approach

Fuzzy comprehensive evaluation is the process of evaluating an objective using the fuzzy mathematics (Chen and Wei, 2002). Based on the principle of fuzzy set theory (Zadeh, 1965), topics such as machine control (Ayag and Ozdemir, 2006), process control (Filev and Syed, 2010) and quality monitoring (Mascle and Zhao, 2008) have seen continual increase in manufacturing during the past decades. Moreover, fuzzy comprehensive evaluation is commonly combined with the analytical hierarchy process (AHP) in solving industrial problems (Abdi, 2009; Chan and Kumar, 2007; Huang et al., 2008). Developed by Saaty (1977), AHP is a decision-making tool for analyzing complex problems with multiple criteria. The literature on AHP in various applications is very rich (Chan and Chan, 2010; Chang et al., 2007; Dagdeviren, 2008; Mendoza, 1997; Sarminento and Thomas, 2010; Sharma and Agrawal, 2009; Wind, 1987). In this paper, the fuzzy comprehensive evaluation combined with the AHP and membership degree analysis was employed as the study methodology.

Table 1
Numeric rating and verbal judgments of preference between factors *i* and *j*.

a_{ij}	Definition
1	Factor *i* is equally important to factor *j*
3	Factor *i* is slightly more important than factor *j*
5	Factor *i* is clearly more important than factor *j*
7	Factor *i* is strongly more important than factor *j*
9	Factor *i* is extremely more important than factor *j*
2, 4, 6, 8	Intermediate values

2.2.1. Determination of the factor set and the appraise set

Suppose that the objective being evaluated contains m factors. The factor set is $U=\{u_1, u_2, u_3, \ldots, u_m\}$; the appraisal set is $V=\{v_1, v_2, v_3, \ldots, v_n\}$; the appraisal of the ith single factor is $R_i=(r_{i1}, r_{i2},\ldots, r_{in})$, which is regarded as a fuzzy subset of V; and the overall fuzzy appraisal matrix of all m factors is:

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \tag{1}$$

Every u_i has a membership for every v_j, and the scores of the qualitative factors are usually given by experts (Wang and Sun, 2010), while the scores of the quantitative factors are calculated using the membership function. In this paper, the objective is to evaluate the environmental performance of EMS in the coating industry in China, and the factor set is the indicator system of the coating industry. Referring to regulations and obligations towards the coating industry, four gradations are selected for the appraisal set $V=\{v_1, v_2, v_3, v_4\}$, and for the single u_i the membership function is constructed as follows:

$$V_4(U) = \begin{cases} 1, & U > x_{3i} \\ 0, & \text{others} \end{cases} \tag{2}$$

$$V_3(U) = \begin{cases} (U-x_{2i})/(x_{3i}-x_{2i}), & x_{2i} < U \le x_{3i} \\ 0, & \text{others} \end{cases} \tag{3}$$

$$V_2(U) = \begin{cases} (U-x_{1i})/(x_{2i}-x_{1i}), & x_{1i} < U \le x_{2i} \\ (U-x_{3i})/(x_{2i}-x_{3i}), & x_{2i} \le U < x_{3i} \\ 0, & \text{others} \end{cases} \tag{4}$$

$$V_1(U) = \begin{cases} 1, & U < x_{1i} \\ (U-x_{2i})/(x_{1i}-x_{2i}), & x_{1i} \le U < x_{2i} \\ 0, & \text{others} \end{cases} \tag{5}$$

where the parameters x_{1i}, x_{2i} and x_{3i} are determined by an expert panel or set according to legal references.