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A methodology for evaluating cleaner production in the stone processing industry: case study of a Shandong stone processing firm

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ABSTRACT

The implementation of Cleaner Production (CP) is a strategy for achieving a corporate's sustainable development and therefore is an important instrument for improving environmental performance. Due to the rapid economic development and urbanization in China, the stone processing industry is developing fast, resulting in several environmental problems. The stone processing sector has begun to implement the CP technologies and practices to tackle with environmental problems caused by the production process. However, the evaluation methodologies of the effectiveness of CP implementation in this sector have rarely been examined in the literature. This paper proposed a CP evaluation system that enables decision-makers to quantitatively evaluate the effectiveness of CP in the stone processing industry. A three-level framework was structured with 6 first-grade indicators and 24 sub-indicators according to the context and characteristics of the stone processing production. And the evaluation criteria were closely related to the laws, rules, regulations and discharge standards in China as well as the current CP technology level. Using analytical hierarchy process and fuzzy membership degree analysis, the weights of each indicators were determined, and evaluation results were achieved. Moreover, the evaluation methodology was verified to be reasonable and practical in the case study of a stone processing firm in Shandong Province. The entire and detailed assessment results demonstrate that the evaluation methodology is helpful in providing guidelines for the implementation of CP strategy in the industry of stone processing.

1. Introduction

Natural stone is one of the most important building materials widely used in many fields due to their inherent hardness, excellent resistance to environmental influence and attractive aesthetics properties (Xu, 2003). Chinese stone industry has proved its consistency and continuity in the commercial arena by supplying over 900 stone types in rich colors and patterns. Stone processing industry is considered as one of the main economic resources and job creation sectors in some regions of China, such as Shandong Province, where the natural stone reserves are abundant. However, the majority of stone processing activities are performed by Small-to-Medium Enterprises (SMEs), whose operations are characterized by low productivity coupled with low penetration of new technologies and an overall lack of environmental management. In addition, environment is polluted by wastewater, noise, and waste residue (i.e. sawdust, crushed slabs and scraps) produced by stone organizations during the processing stage, as shown in Fig. 1.

Baas (1995) defines cleaner production (CP) as the conceptual and procedural approach to production that demands all phases of the life-cycle of a product or a process should be addressed with the objective of prevention or the minimization of short and long-term risks to environment. To implement CP strategy, lots of technological innovations were developed in stone processing industry in the past decades. Many enterprises had adopted numbers of technological innovations as panaceas in order to maintain their economic and environmental sustainability. However, in fact, consistent with Silverstre and Silva (2014), CP technologies alone did not solve the sustainability issues faced by the sector, especially because of the aimless and passive adoption by firms in China. This situation generates the following questions: Does a firm benefit from implementing its existing CP strategy? How does the presence of the CP practices in a firm affect its operational and ecological performance? How can a firm obtain the greatest environmental benefits by choosing and adopting some advisable CP technologies under the condition of limited funds? The effectiveness of CP must

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Fig. 1. The environmental issues caused by stone processing industry. (a) stone processing workshop (b) sawdust (c) wastewater (d) crushed slabs and scraps.

be evaluated scientifically to provide guidelines for implementing CP strategy. Unfortunately, there is not any complete and quantitative evaluation system or criteria for evaluating the stone processing production in China.

In this paper, we draw from sustainability, cleaner production and CP technologies in the stone sector, as well as CP evaluation method to build our theoretical approach. Firstly, we build on the relationship among sustainable development, CP strategy and CP technologies in stone processing industry. Since evaluation of the effectiveness of CP is a prerequisite for incorporation of suitable technological innovations into CP practice and implementing CP strategy in stone processing sector, we rely on CP evaluation literature to complement our theoretical approach.

Through this paper, we aim to establish a relatively systematic and appropriately evaluated framework and criteria, using the Fuzzy AHP model to assess the production process of stone products. This paper offers three key contributions. Firstly, from an academic perspective, this study integrated an indicator framework and a number of criteria from various literature of CP technologies and experts' experience in the stone sector. Then indicator frame and criteria were combined the with Fuzzy AHP model to construct the CP evaluation methodology that would be used to help assess the implementation of CP strategy. Secondly, from a practical perspective, the methodology is a tool that enables a stone processing organization to systematically evaluate the level of CP, and which helps managements visualize the key affect indicators, identify the existing problems and establish strategies to achieve CP goals. Thirdly, for the government departments, the methodology can be used as management tools to assist them to grasp the production level of the industry, provide the basis for macroscopic management and the policy formation.

This paper is organized as follows: In section 2, drawing from literature on sustainability, cleaner production, CP technologies and evaluation, we develop our theoretical framework. Section 3 lays the groundwork for developing the CP evaluation methodology. Section 4 develops the evaluation system including the indicator framework and criteria, as well as the Fuzzy AHP model. Section 5 applies the CP evaluation method to a case firm, and presents the results and major finding. Then we develop the discussion with implications for research, strategy and policy in section 6, followed by conclusions in section 7, where we depict the main research contributions, the limitations of this research and avenues for future research.

2. Theoretical framework

2.1. Sustainability, cleaner production and CP technologies

According to the world commission on environment and development (WCED, 1987:46), sustainable development is "… exploitation of resource, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations …". Since the United Nations Conference on Environment and Development in 1992, this concept of sustainable development is increasingly becoming a public concern. What started as a discourse among specialists has now become an important objective of policy makers, industries and media agendas (UNCED, 1992). Efficiency in energy consumption and emission reduction in various products and processes is required from markets, and industries can no longer neglect this demand. Considering environmental aspects have been given different names such as Ecodesign, Design for the Environment, Environmentally Conscious Design, Green Engineering, Sustainable Design, or Design for Sustainability amongst others (Waage, 2007; Howarth and Hadfield, 2006; Karlsson and Luttropp, 2009).

The World Commission on Environment and Development (WCED, 1987) also stressed the urgency of meeting the needs of present and future generations in an environmentally sound way. Thus, efficiency in resource consumption in industrial activities is regarded as a key strategic for a successful business. However, the solution to this puzzle is not a trivial one, being especially difficult for the resource-dependent industry. For these industries, cleaner production (CP) is more likely to be proposed to develop the operationalization of sustainable development strategy (Arun and Dirk, 2006; Jovan et al., 2010; Gang. C et al., 2014; Silvestre and Silva, 2014). One of the earliest attempts to conceptualize CP was given by the United Nations Environmental Program (UNEP), which defines the term as a "preventive strategy which promotes waste before it is systematically created, to systematically reduce pollution, and improve the efficiencies of resource use" (UNEP, 2001, p.3). A number of other general definitions about CP have emerged from then on (e.g. Huisingh and Baas, 1991; Jackson, 1994; Wang, 1999). Despite the multiplicity of interpretations, according to Silverstre and Silva (2014), the concepts of CP have evolved substantially, and all definitions base on the thought of CP: i) meaning the continuous application of an integrated environmental strategy to both processes and products to reduce environmental impact; ii) including conserving natural resource and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions; iii) focusing on reducing environmental impacts throughout the entire life cycle of the product; iv) achieved by applying expertise, improving technology and changing attitudes.

Specific to stone processing sector, CP has been recognized for its ability to embody the efficient use of natural stone resources and to minimize wastewater and solid waste as well as risks to human health and safety (Silvestre and Silva, 2012). Furthermore, introducing CP mode into the stone processing industry would reduce the production costs, decrease the load of the terminal treatment, and improve its environmental performance and social benefits. According to Hilson (2003), CP is increasingly being associated with environmental improvements resulting mainly from technological innovations in the stone quarrying and processing industry. In fact, CP technologies have been increasingly assumed the role of key