Linking Green supply chain management with environmental Technologies and an application of technology selection

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Abstract

In this paper, relations between green supply chain management and environmental technologies are presented. Environment technologies are taken as preventing the pollution in forward supply chain, controlling pollution in reverse supply chain and technologies that improves the environmental performance in integrated supply chain. In the study, key criterion of technology selection is evaluated with Fuzzy AHP (Analytical Hierarchy Process); their priorities are defined and by using these priorities technology selection is made. Having a significance part in company's total cost, proper and suitable selection of technology investment is emphases.

Keywords: Green supply chain management, Environmental technology, Fuzzy AHP

1. INTRODUCTION

Today, by becoming more complex, the importance of environment-related activities has been extended in parallel to the improvements in environmental technology. The reason for this shift can be connected with the fast growth of industrialization in the world; the environmental and ecological impacts of products have become a major issue. Vachon (2008) emphasizes the relationship between environmental technologies and green supply chain practices.

Playing a significant role in environmental technologies, if used efficiently and effectively, environmental technology is capable of being useful for the management of environment-related activities. Efficient and effective usage can only be gained if the technology is appropriate for the company. Wrongly selected technology can bring ineffective solutions and failure in environment-related activities. According to Hsu et al. (2010) technology selection is a multiple criteria decision-making problem. Among these, the Fuzzy Analytic Hierarchy Process (FAHP) is one of the most popular methods. People often use knowledge

that is imprecise rather than precise. The fuzzy set theory approaches could resemble human reasoning in use of approximate information and uncertainty to generate decisions.

Because of the continuous increase in environmental costs, the effects of environmental issues on decision making process are getting more important (Schaltegger, 2000). In this paper, a study concerning environmental technology selection criteria for the mining industry is reported.

The analysis has been executed adopting the FAHP technique, a fuzzy multi-attribute decision-making methodology that has been developed due to the imprecision in assessing the relative importance of attributes and the performance ratings of alternatives with respect to attributes. The work is structured in the following manner. In Section 2, a literature review of the green supply chain management is given. In Section 3, environmental technologies are grouped. In Section 4, the fuzzy AHP methodology is defined. An evaluation of technology alternatives, the proposed methodology and results are fully shown in Section 5. Finally, conclusions and considerations are reported in Section 6.

2. Green Supply Chain Management

Green supply chain management (GrSCM) has its roots in both environment management and supply chain management literature. Adding the "green" component to supply chain management involves addressing the influence and relationships between supply chain management and the natural environment. Similar to the concept of supply chain management, the boundary of GrSCM is dependent on the goal of the investigator. The definition and scope of GrSCM in the literature has ranged from green purchasing to integrated green supply chains flowing from supplier to manufacturer to customer, and even reverse logistics (Zhu and Sarkis, 2004).

GrSCM is gaining an increasing interest among researchers and practitioners of operations and supply chain management. The growing importance of GrSCM is driven mainly by the escalating deterioration of the environment, e.g. diminishing raw materials resources, overflowing waste sites and increasing levels of pollution. GrSCM is integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life (Srivastava, 2007).

Environmental management can be defined as the management of human's interactions with environment and their impacts on environment. Environment management has developed significantly from its early stages in the late 1960s and early 1970s. Early environmental

efforts were based on controlling pollution emerging from individual sources. However, environmental management evolved into a systematic attempt to prevent pollution at the source and manage entire ecosystems in the 1990s (Nikbakhsh, 2009). Today, in order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain. GrSCM has emerged as a way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency (van Hoek, 2000).

3. Environmental Technologies

Environmental technologies can be defined as not only by the changes in the environment area but also with the new techniques and information containing environmental management systems, design and engineering for environment (Klassen and Whybark, 1999). Environmental technologies in manufacturing include implementing environmental audits of manufacturing facilities, reformulating products to lower their environmental impacts, covering open process tanks to reduce evaporation, training employees to prevent process leaks, and cleaning up underground storage tanks that leak. An environmental technology characterizes three categories based on the operations strategy literature: pollution prevention, pollution control, and management systems.

Pollution prevention technologies: The term “pollution” refers to all nonproduction outputs, irrespective of any recycling or treatment that may prevent or mitigate releases to the environment. Pollution is the undesirable change in the physical, chemical or biological characteristics of air, land, and water that may or will harmfully affect human life or that of other desirable species, living conditions; or that may or will waste or deteriorate our raw material resources. The term “pollution prevention” refers to the combination of industrial source reduction and toxic chemical use substitution (Noyes, 1993). Pollution prevention technologies are defined as structural, not infrastructural, investments that reduce or eliminate pollution at the source (Vachon, 2007).

Pollution control technologies: Pollution control has traditionally been carried out through two alternatives. 1. End-of-pipe treatment refers to the application of chemical, biological, and physical processes to reduce toxicity or magnitude of undesirable compounds to the environment. 2. Disposal involves the use of post process activities that can handle waste or hazardous materials at waste-management facilities (El-Halwagi, 1998). Pollution control technologies are also structural investments that ensure a proper disposal of waste, reduce the release of pollutants, or correct past environmental damages (Vachon, 2007).

Management Systems: These environmental technologies are infrastructural investments that affect the way manufacturing is managed. They include efforts to formalize procedures for

evaluating environmental impacts during capital decision budgeting, to increase outside stakeholder involvement in managing operations, to increase employee training for spill prevention and waste reduction, to establish an environmental department, and to develop new procedures for cross-functional coordination (Klassen and Whybark, 1999).

As being a close-loop supply chain, green supply chain is evaluated under two parts; forward and reverse supply chain, which is seen in the Figure 1. From the definitions of the environmental technologies, we propose three assumptions.

1. In forward supply chain, pollution prevention technologies have an important part in the physical flow of material, production and distribution.
2. In reverse supply chain, which consists of consecutive flows of collecting, transformation, assembly and re-manufacturing, pollution controlling technologies come forward. As a result of the pollution occurrences, controlling mechanisms will be used.
3. All the innovations, changes and technologies in the environmental issues are the part of the management system of the green supply chain.

4. Evaluation of Environmental Technologies with FAHP

Analytic Hierarchy Process (AHP) is one of the well-known multi-criteria decision making techniques that was first proposed by Saaty (1980). Although the classical AHP includes the opinions of experts and makes a multiple criteria evaluation, it is not capable of reflecting human's vague thoughts. The classical AHP takes into consideration the definite judgments of decision makers (Secme et al., 2009). By integrating fuzziness in AHP, prejudice or bias of the decision makers can be eliminated.

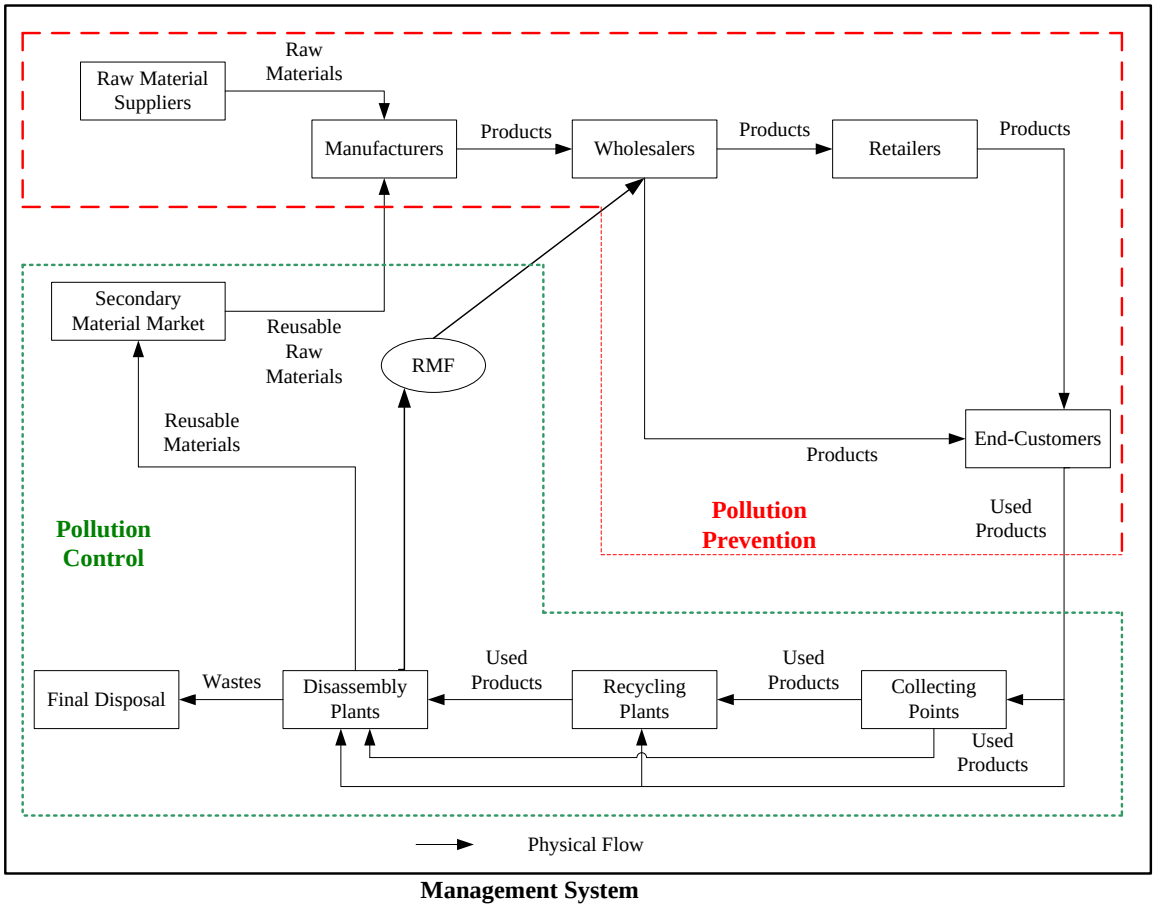

Figure 1. Interactions between GrSCM and environmental technologies (Sheu et. al. 2005)

Chang's extent analysis (Chang, 1996) for FAHP will be used in this study. Triangular fuzzy fuzzy numbers are used in the evaluation model of this paper.

In this study, total of 9 criteria organized under 3 main criteria. The model ends with the alternatives that represent three different technologies. They have been chosen in order to represent different families of technology, which can be roughly assumed to be a first step to identify the right technology. The goal is the optimal selection of the environmental technology that fits the actual needs of the mining facility. By using the decision criteria selected from the literature and interviewed with one decision maker, environmental technology is evaluated for mining industry. In Figure 2, the hierarchy that has been defined and built to help in the technology selection process is shown.

From Table 1, weight vector W = $(0.331, 0.300, 0.369)^T$ is calculated. The *pressure* criterion is the dominant factor, following by *physical* and *financial* factors in the technology selection procedure. Weight vectors for the sub-criteria are evaluated in the same way, but due to the page limitations they aren't given here.

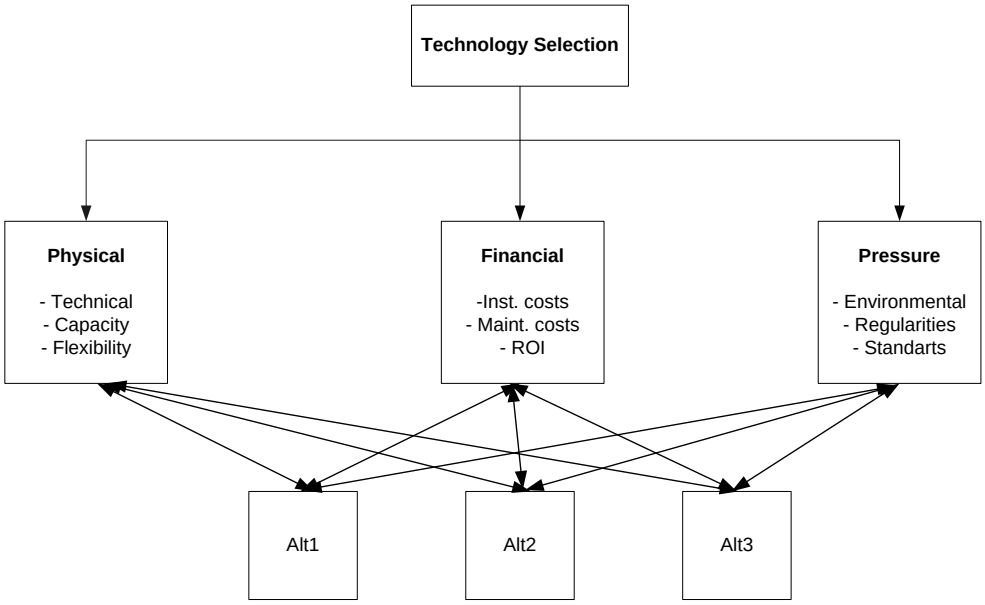

Figure 2. Hierarchical structure of the decision model

Table 1. Fuzzy pair-wise comparison matrix

	Physical	*Financial*	*Pressure*
Physical	**(1, 1, 1)**	(1/2, 1 , 3/2)	(2/3, 1, 2)
Financial	(2/3, 1, 2)	**(1, 1, 1)**	(1/2, 2/3, 1)
Pressure	(1/2, 1 , 3/2)	(1, 3/2, 2)	**(1, 1, 1)**

Although having similar weights, from the three alternative technologies, first alternative should be selected by the company which has the weight of 0.384, according to the Table 2. By integrating FAHP in technology selection process, the decision-maker is able to give more precise, sensitive and unbiased decision for these three alternatives.

Table 2. Main criteria and alternative weights

	Physical	*Financial*	*Pressure*	*Weighted values of main criteria*
Weights	0.331	0.300	0.369	
Alternatives				
Alt1	0,378	0,413	0,365	0.384
Alt2	0,247	0,287	0,271	0.268
Alt3	0,373	0,298	0,363	0.346

5. CONCLUSION

Used in a fuzzy environment for decision-making, the fuzzy AHP is one of the multi- criteria decision-making methods. In this study AHP is used for selecting the best environmental technology from three different alternatives. For determining the criteria, interviews were conducted with the environmental experts of the company, and questionnaires were used for the evaluation process. The fuzzy AHP method can deal with the ratings of both quantitative as well as qualitative criteria and select the suitable software effectively. It's seen that the fuzzy AHP method may be a useful additional tool for the problem of technology selection in environment management systems.

In this study, the selection of the environmental technologies is evaluated under physical, financial and pressures criteria and their sub-criteria. The results show that the pressures criterion has the most significant weight in the selection process. According to the sub-criteria results, technical properties in physical criterion, installation costs in financial criterion and environmental issues in pressures criterion are the most important sub-criteria.

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