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Economic analysis of paper recycling vis-à-vis wood as raw material

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Abstract

Concerns for the environment has forced many firms define policies that protect the environment within which they operate. This paper presents a linear optimization model for paper industry to compare total system cost of wood as a raw material with recycling of waste paper. Objective of the proposed model is to minimize the cost of paper in the supply chain. Costs included in the objective functions are: costs for collection of raw material, transportation, inventory, manufacturing, segregation and disposal (during recycling). The model also includes the economic implications of using these alternative material sources on environment as well as quality of final product. To gain further insights into system behavior, sensitivity analysis, shortage analysis and indifference curve analysis have been performed. The analysis clearly reveals that the paper recycling is an economical option compared to wood as a raw material. The paper analysis highlights various strategies that could be followed under different market conditions.

Keywords: Supply chain; Paper industry; Cost optimization; Indifference curve

1. Introduction

Environmental issues are becoming increasingly important for the product designers and manufacturers. The traditional assumption that the cost of ecological burdens is to be shared by the society as a whole is no longer acceptable. In several countries, waste management policies are characterized by the hierarchy of options in which waste minimization, reuse and material recycling are all considered preferable to energy recovery. This concern for the environment has motivated increased interest in the reverse material flows, which has become the subject of growing attention over the last decade (Fleschmann et al., 1997).

The reverse flow is a part of a closed loop supply chain, which consists of forward supply chain and reverse supply chain. According to the Council of Reverse Logistics Management, reverse logistics is defined as the process of planning and controlling the efficient, cost effective flow of raw material, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Krumwiede and Sheu, 2002). The initiatives that generate a reverse flow are basically of three types (Murphy, 1986): from customer who returns goods, from industry

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interested in recycling and from the government which aims to promote practices of this type. Recent reviews and literature compilation either on models to support reverse logistics or on the business prospective could be found in Fleischmann et al. (1997) and Guide et al. (2000).

Waste accumulates over time unless decomposed in the ecosystem or recycled. Waste is a strategic issue for a variety of reasons. Companies are seeking to reduce cost by minimizing all types of waste in the supply chain. There has been a considerable increase in the degree of national and international regulation and legislations governing waste management. Finally, the customers are becoming more concerned about the impact of product and services on the environment. Correspondingly, organizational paradigms have been created as ecological and environmental issues play a more important role in corporate strategies (Sarkis, 1995). Piler et al. (2004) suggests that the management of reverse logistics may suppose a significant difference with respect to the competitive edge of the firm within the industry and become a beneficial as well as sustainable business strategy for the company. This new concern has led companies to develop strategies that integrate environmental management (Brysson and Donohue, 1996; Handfield et al., 1997); in many cases actually constituting a competitive edge for the organization (Sarkis, 1995; Autry et al., 2001). Due to these reasons, waste management has received increasing attention in the last decades and the emphasis has been shifting towards recycling as one of the alternative ways of managing waste.

Several researchers have used functional methods to model waste and waste management process. Sarkis (1995) modeled the product development lifecycle and its impact on the environment using the integrated CAM functional modeling method, known as $IDEF_0$ (Bravoco and Yadev, 1985). A functional model of the supply chain for waste management, product recovery and reuse that gave an idea about the forward and return flows of material was investigated by Thierry et al. (1995). Far reaching policy measures have also been undertaken in many economically advanced countries, to promote recycling of municipal waste. Huhtala (1997) use dynamic models to analyze waste management in general. He has developed a model for determining optimal levels of material recycling and land filling, in which recycling benefits from a contingent valuation study are included. Incineration is however not included. Eichner and Pethig (2001) use a static general equilibrium model to study efficiency restoring policies. In their model, material is first extracted, then used for producing a consumption good, recycled and finally treated to reduce environmental damage.

The composition of waste collected by the waste pickers in Mumbai, India (Beukering et al., 1996) and the composition of municipal waste in an advanced economy, the USA (EPA, 2000) reveal that the proportion of plastic and paper in waste generated are very significant and need immediate attention in order to save the environment from getting polluted. Recycling provides a better option to reduce paper and plastics wastes. Studies specially addressing the problems related to the issues of recycling of wastes/hazardous wastes such as effluents, glass, plastics, paper, etc. are fewer (Koo et al., 1991; Stepnowski et al., 2002; Bartels, 1998; Van Notten, 2000; Gupta and Chakraborty, 1984; Chang and Wei, 2000). The driving forces behind the above-mentioned studies were primarily cost saving or concern for environment (through regulations or motives). Recycling is thus one of the most important techniques through which the rate of degradation of the environment can be slowed down.

However, there exists limited literature on the economic analyses for recycling of paper to assist the management in decisions-making, formulating policies and strategies. Recent publications about wastepaper concentrate on the high volatility of wastepaper prices (Ackerman and Gallagher, 2002), examine inter-country differences in wastepaper recovery and utilization (Bystrom and Lonnstedt, 1995; Berglund et al., 2002) or discuss whether wastepaper should be recycled or incinerated (Hanley and Slark, 1994; Leach et al., 1997; Hekkert et al., 1999; Samakovlis, 2003; Klieineidam et al., 2000). Grace et al. (1978) and Yohne (1979) carried out economic studies of the supply and demand or trade, with wastepaper. They examined international trade and its importance to price. Price expectations and the effect of price changes have been analyzed by Edwards (1979), Deadman and Turner (1981), and Kinkley and Lahiri (1984). Anne and Timo (1998) and Huttunen and Pirttila (1998) analyzed the structure of the recovered paper market. Both the researchers use statistical approach supported with a qualitative market analysis to get a view of the short-term price trend.