PERGAMON

Transportation Research Part E 38 (2002) 457–473

TRANSPORTATION RESEARCH PART E

www.elsevier.com/locate/tre

A reverse logistics cost minimization model for the treatment of hazardous wastes

Tung-Lai Hu [a], Jiuh-Biing Sheu [b,*], Kuan-Hsiung Huang [c]

[a] *Department of Industrial Engineering, National Taipei University of Technology, 1, Sec. 3, Chung-Hsiao E. Rd. Taipei 106, Taiwan, ROC*

[b] *Institute of Traffic and Transportation, National Chiao Tung University, 4F, 114 Chung Hsiao W. Rd., Sec. 1 Taipei 10012 Taiwan, ROC*

[c] *Department of Transportation, Warehousing and Logistics, National Kaohsiung First University of Science and Technology, 1 University Road, Yuanchau, Kaohsiung 824, Taiwan, ROC*

Received 24 September 2001; received in revised form 15 March 2002; accepted 11 April 2002

Abstract

This study presents a cost-minimization model for a multi-time-step, multi-type hazardous-waste reverse logistics system. A discrete-time linear analytical model is formulated that minimizes total reverse logistics operating costs subject to constraints that take into account such internal and external factors as business operating strategies and governmental regulations. Application cases are presented to demonstrate the feasibility of the proposed approach. By using the proposed model coupled with operational strategies, it is shown that the total reverse logistics costs for the applications cases can be reduced by more than 49%.

Keywords: Reverse logistics; Hazardous wastes management; Discrete-time; Cost minimization

1. Introduction

Hazardous-waste reverse logistics may be useful for solving waste-induced environmental pollution problems that accompany high-technology industrial development. Here reverse logistics is referred to as the process of logistics management involved in planning, managing, and controlling the flow of wastes for either reuse or final disposal of wastes. The traditional measures, i.e., waste processing technologies, used for the treatment of hazardous wastes are inadequate for

* Corresponding author. Tel.: +886-2-2349-4963; fax: +886-2-2349-4953.
E-mail address: jbsheu@cc.nctu.edu.tw (J.-B. Sheu).

1366-5545/02/$ - see front matter
PII: S1366-5545(02)00020-0

integrating waste management, collection, storage, distribution and transportation activities into comprehensive, reverse logistics operating strategies. Consequently, it is difficult to coordinate these activities in a hazardous-waste reverse logistics system for reducing environmental pollution. For example, 1.47 million metric tons of hazardous wastes are reportedly produced every year in Taiwan. However, only 40% of them can be efficiently disposed of, due to the limited capacity of Taiwanese hazardous-waste processing facilities (Wei and Huang, 2001).

Although there is an increasing amount of research on reverse logistics (Stock, 1992; Cairncross, 1992; Pohlen and Farris II, 1992; Jahre, 1995; Kroon and Vrijens, 1995; Stock, 1998; Shih, 2001), studies specifically addressing hazardous wastes problems (Peirce and Davidson, 1982; Jennings and Scholar, 1984; Zografos and Samara, 1990; Koo et al., 1991; Stowers and Palekar, 1993; Nema and Gupta, 1999) are rare. It is noteworthy that previous literature appears to be devoted mainly to the optimization of reverse network configurations, including transportation routes, as well as the size and location of disposal facilities for hazardous waste management. An early example is the study by Peirce and Davidson (1982), which utilizes a linear programming model to formulate the optimization problem of transportation routing among transfer stations, disposal facilities, and long-term storage impoundments. Herein, their study may be limited to the identification of the optimal waste distribution routes under the condition that waste treatment facilities as well as specific waste processing technologies are given. The issue of transporting multiple types of wastes is investigated in Jennings and Scholar (1984), which formulates the regional hazardous waste management system (RHWMS) as simply a vehicle routing problem in an attempt to accomplish the goal of either minimum cost or minimum risk. In contrast, the study by Zografos and Samara (1990) deals only with the problem of a single type of waste; however, their method serves three objectives, including the minimizations of transportation risk, travel time, and disposal risk. In addition to vehicle routing, issues with respect to locating waste storage and treatment facilities are investigated in Koo et al. (1991) where fuzzy theories together with multi-objective optimization techniques are utilized for the facility planning of hazardous waste treatment centers in South Korea. Similar attempts can also be found in Stowers and Palekar (1993) and Nema and Gupta (1999). However, the scope of the aforementioned research is still limited to some specific areas of hazardous-waste reverse logistics.

Despite the advances made in the prior literature, hazardous-waste reverse logistics warrants more research. Similar viewpoints can also be found in Fleischmann et al. (1997) in which the field of reverse logistics is classified into three main areas: (1) reverse distribution planning (Pohlen and Farris II, 1992; Jahre, 1995), (2) inventory control of return flows (Schrady, 1967; Barros et al., 1998), and (3) production planning with reuse of parts and materials (Johnson and Wang, 1995; Penev and de Ron, 1996; Richter, 1996; Spengler et al., 1997). In Fleischmann et al. (1997), the interface between reverse logistics activities is particularly emphasized. Carter and Ellram (1998) further point out that in most of previous literature, there is a lack of well-grounded, conceptual frameworks for reverse logistics. Moreover, the variety of material characteristics of hazardous wastes coupled with diverse environmental regulations has made hazardous-waste treatment problems more complex, thus requiring specific solution measures such as control and management of reverse logistics.

In view of the lack of in-depth investigation with respect to hazardous-waste reverse logistics operations in the literature, herein we formulate a hazardous-waste reverse logistics cost model using a multi-time-step, multi-type operations process that minimizes the logistics costs. More