清水建設研究報告
第77号平成15年4月

建設産業における静脈物流システムの設計

中村　裕幸
（技術研究所）

Design of Reverse Logistic System for Closed Loop Supply Chains in The Construction Industry

by **Hiroyuki Nakamura**

Abstract

Construction logistics in a recycling-conscious society consists of "conventional logistics" and "reverse logistics." With regard to the use of materials and investment in production, distribution, and logistics systems that constitute the conventional logistics, decisions are made based on economic evaluations. As regards the reverse logistics, environmental issues standout from all other issues, but they are difficult to evaluate economically, and the logistics has been improved mainly in terms of public infrastructure. These two unique characteristics prevent the concept of economic evaluation from integrating these two types of logistics into a system that can be used to create a recycling-conscious society. The author believes that the economic principle must be introduced into the reverse logistics in order to allow construction logistics to function as one element of a system in a recycling-conscious society. Based on this principle, the author has designed a reverse logistics system.

概　要

循環型社会における建設ロジスティクスは、動脈物流と静脈物流で構成される。動脈側を構成する資材の使用や生産・物流・流通システム等に対する投資は、経済的評価をもとに意思決定が行われている。一方、静脈側では経済的評価の行いにくい環境問題の側面が強く、公共のインフラストラクチャーとして整備されてきたため、両者を統合した循環型社会システムとして経済評価を行う際の障害となっている。筆者は、循環型社会システムのひとつの要素として建設のロジスティクスを機能させるには、静脈側に経済原理を導入することが必要であるとの考えに基づき、下記を条件とする静脈物流システムを設計した。設計内容を報告する。

① 都市環境向上のため、車両台数を低減し、同時に回収効率を向上させる物流システムであること。

② 廃棄物の不法投棄防止、再資源化の原材料としての品質および量の確保、さらに再資源化に伴って発生する費用や収益の再分配の観点から、トレーサビリティを担保できること。

③ 産業廃棄物の取引市場形成や市場競争力の強化のための情報生成と整理、生成情報を提供する情報システムとそれを運用する体制（静脈卸）を含むこと。

§ 1. Introduction

Various actions are being taken to establish a recycling-conscious society. The Basic Law for Promoting the Creation of a Recycling-conscious Society promulgated on June 2, 2000, defines a recycling-conscious society as "a society where products are prevented from turning into waste, and products, if turned into recycled resources, are put back into circulation; recycled resources, if unable to be put into circulation, are appropriately treated and disposed of, thereby reducing the total consumption of natural resources and minimizing the impact on the environment." Ueda [1] added to this definition, saying, "It is not a society that tries to recycle generated waste based on the existing technical structure or society system that mass-generates waste, but a society that establishes the most environmentally friendly relationship between human activity and nature by changing the very mechanism of the technical structure or socioeconomic system from mass-disposal to recycling."

Using the latter definition as a guide, the author discusses the possibility of achieving a recycling-conscious society from the viewpoint of construction logistics.

Japan's construction industry consumes 46% of the country's total raw materials consumed by all industries, and discharges 21% of these raw materials as industrial waste. The rate of recycling of the waste from the construction industry is around 55%, while that for other industries is 83% on average (Figure 1). It is a conventional concept to emphasize developing recycling technology and improving efficiency in order to create a recycling-conscious society. It is, however, equally important to focus on "the process from emission to pre-treatment" before applying recycling technology, and on "issues related to market flow or market competitiveness with regard to products made from re-used or recycled materials" after applying recycling technology. In this light, a system is necessary that can organically combine distribution, which includes the process popularly called "recycling," as well as the flow of information, and the flow of commercial transactions. A reverse logistics system that is based on construction logistics and is composed of these elements should be established.

Recycling-conscious construction logistics also consists of conventional logistics and reverse logistics. Decisions regarding the use of materials and investments in production, distribution, distribution system, etc., that constitute the conventional logistics, are made based on economic evaluations. As regards the reverse logistics, environmental issues standout from all other issues, but they are difficult to evaluate economically, and the logistics has been improved mainly in terms of public infrastructure. These two unique characteristics prevent the concept of economic evaluation from integrating these two logistics into a system that can be used to create a recycling-conscious society. The author views construction waste as raw materials for recycled products and has designed reverse logistics for construction-waste recycling factories based on the principle that the economic factors must be introduced into the reverse logistics in order to allow construction logistics to function as one element of a system for a recycling-conscious society.

Given the fact that "logistics" is generally considered identical to conventional logistics (distribution), this report uses reverse logistics as a term meaning reverse distribution. The term "physical distribution" is used when it specifically means the collection and transportation of waste.

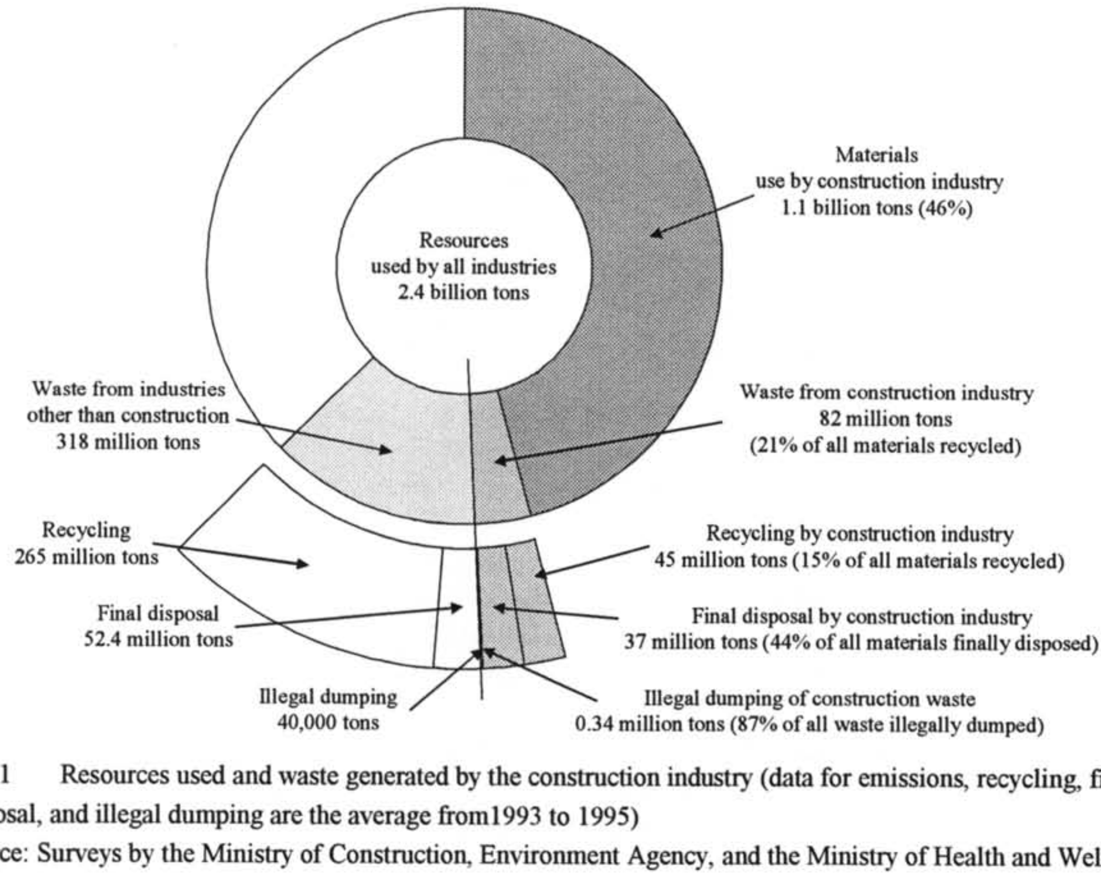

Fig. 1 Resources used and waste generated by the construction industry (data for emissions, recycling, final disposal, and illegal dumping are the average from1993 to 1995)

Source: Surveys by the Ministry of Construction, Environment Agency, and the Ministry of Health and Welfare

§ 2. Physical Distribution Model For Construction Waste

The current physical distribution of construction waste is modeled in Fig. 2.

Construction byproducts generated at various construction sites, which are waste generators, are recycled and finally disposed of through the five routes shown in the figure. Illegal dumping takes place in the third (α) and fifth (β) routes.

According to statistics from the Waste Response Section, Environmental Sanitation Department, Water Supply Bureau, Ministry of Health and Welfare, the total amount of waste generated by all industries in 1997 was 415 million tons, of which 169 million tons were recycled and 67 million tons were finally disposed of. Intermediately treated waste was 301 million tons and incinerated[i] 179 million tons.

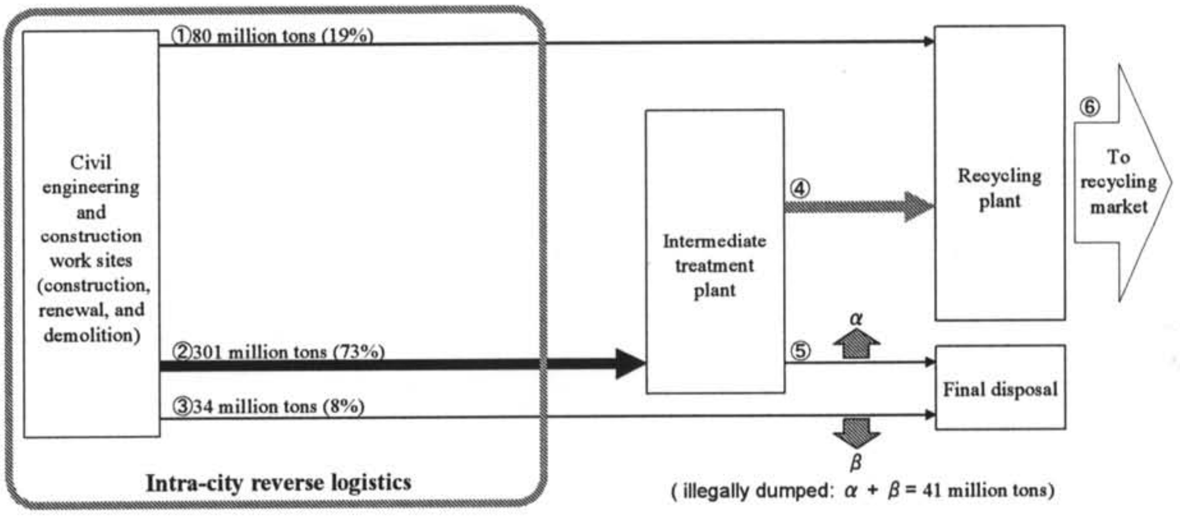

Fig. 2 Reverse logistics model
Source: Statistics (in 1997) from the Waste Response Section, Environmental Sanitation Department, Water Supply Bureau, Ministry of Health and Welfare.

Table 1 Objectives set for each of these three elements as well as the tools necessary to achieve them.

	Safe and transparent	Public- and society-oriented	Efficient and economical
Objectives	•Appropriately treat and dispose of waste; include a mechanism to prevent illegal dumping •Traceability •Quality assurance of waste	•Reduce CO2 emissions from vehicles •Reduce traffic volume in urban areas •Reduce the amount of waste to be put to final disposal	•Improve waste transport efficiency •Improve construction waste material recycling •Highly efficient, small-volume collection of waste
Enabling tools	•Provide information on the Internet (shipment and arrival of waste and recycled waste by type) •Track vehicles by GPS •Establish quality investigation method and quality assurance structure for waste	•Set prices to allow automatic application of incentives by type-specific collection •Collect, sort, and transport waste without type mixing •Disclose IT mechanism and distribution mechanism	•Provide information from data center •Collect waste by cooperative waste collection activities •Treat process, and distribute waste at reverse logistics center (pulverization and compaction) •Provide a stable supply of waste of standard quality to recycling plants

Numerically speaking, the first, second, and third routes account for 80 million tons (19%), 301 million tons (73%), and 34 million tons (8%), respectively. No data for the fourth and fifth routes has been published. The amount of waste illegally dumped in the same year ($\alpha + \beta$) was 41 million tons.

§ 3. **Design Of Reverse Logistic System**

3. 1 Design requirements for reverse logistics system

A systematic mechanism for the reverse logistics that is "safe and transparent," "public- and society-oriented," and "efficient and economical," should be established in order to create a recycling-conscious society.

Table 1 describes the objectives set for each of these three elements as well as the tools necessary to achieve them.

Based on Table 1, the following design requirements have been established for a reverse logistics system.

1) The distribution system should ensure efficient collection of waste with a smaller number of collecting vehicles in order to improve urban environments.

2) The distribution system should provide for the tracing of waste from the viewpoints of preventing illegal dumping of waste, assuring a certain level of quality and a certain amount of waste to be used as raw materials for recycling, and distributing the costs and revenues arising from recycling.

3) The distribution system should be able to generate and organize information to be used to help set up a market for waste transactions and strengthen market competitiveness, and should include systems for distributing such information and operating the information system.

3. 2 Examples of a reverse logistics system design

Examples of designs that satisfy the above requirements are described below, along with the conditions in common that allow such designs to be realized:

- Containerization of waste and the labeling of such containerized waste with an ID tag (agreement between "material" and "information")
- Control of distribution of unit-loaded waste using information technology (information control)
- Stable supply of recycling resources to help enlarge the recycling market

1) The concept is to set up reverse logistics centers at various locations in a city and collect small quantities of waste by frequently cruising the city. In this concept, large intermediate treatment plants are located in suburban areas. In metropolitan areas, garbage trucks must deal with traffic congestion in the city in order to gather the large quantities of waste produced in the center of the city. Currently, the typical practice in big cities in Japan is to use 4-ton trucks to collect waste twice a day using an intermediate treatment plant as a base. This requires the intermediate treatment plant to operate a relatively large number of trucks in order to cover the collection territory. In reality, such practice suffers from poor transportation efficiency, degrades the urban environment, and increases transportation costs due to the inevitable increase in the number of trucks needed. But since traveling in the core area is relatively easy (a small-size refuse collector operating an intermediate treatment plant in the Tokyo Metropolitan area now collects waste four times a day on average), it would be possible to improve collection efficiency and reduce the number of trucks needed by setting up reverse logistics centers capable of temporary storage of waste and area-specific sorting of waste for mass-transport in large trucks to surrounding intermediate treatment plants. By providing highly frequent and precise type-specific collection services, this system would particularly benefit the large number of small construction sites that are found in a city area and that have limited space in their own compounds for waste storage.

2) The second concept is to use a Global Positioning System-based byproduct transportation control system to handle information about the location, quantity, and quality of waste. In order to trace waste, information about the location of the waste, such as where the waste is deposited, where it is collected, or to where it is to be transported, should be synchronized with a time history of such operations. In this concept, a container or a 4-ton truck holds the waste. The driver of a garbage truck should input data regarding the quality, content, and quantity of the waste so that a unique ID number can be assigned to the waste by the control system. These ID numbers would then be checked every time the waste is off-loaded at the reverse logistics center or intermediate treatment plant.

3) The third concept is to integrate information from an industrial waste transport management system and other waste-related information in order to establish a reverse logistics service center (RLSC) that provides the market with information about the environment and the waste. The economy in the conventional sector is mainly determined by economic values. The waste problem in the reverse logistics, however, is strongly associated with environmental issues that are difficult to measure in terms of economic value. This is why the reverse logistics resists a smooth change to a recycling-conscious socioeconomic system. To achieve such a change, it is necessary to establish a function to integrate and provide waste-related information that helps the market to evaluate the economic value of the waste. In this concept, "conventional wholesale business," which corresponds to "reverse wholesale business," is used to adjust the quality and quantity of waste to be taken as raw materials to recycling plants.

An outline of a reverse logistics system design based on a review of these considerations is shown in Fig. 3.

§ 4. Conclusions

A reverse logistics system was designed with the goal of generating the waste-related information necessary for its economic evaluation. The system can trace construction waste, promotes the establishment of an industrial waste market, and reinforces the competitiveness of the construction waste to be marketed.

This reverse logistics system design may promote the change to a recycling-conscious society by contributing to the following three major areas.

1) Improves the recycling ratio (resources recycling rate) by developing a recycling-conscious construction production system formed by combining reverse and conventional logistics, and by reducing CO2 emissions through further recycling of resources.

2) Eliminates road traffic congestion and improves roadside and urban environments by developing a materials transport system through integration of conventional and reverse logistics.

3) Improves the efficiency of existing industries in the surrounding area by the maturation of reverse industries, and increasing employment through the growth of emerging industries

A byproduct transportation management system using a GPS-based modified event trigger function is being tested at a construction site managed by Shimizu Corporation and under the joint supervision of Shimizu Corporation, Yuwa Co., Ltd. (intermediate treatment specialist) and NTT East Japan.

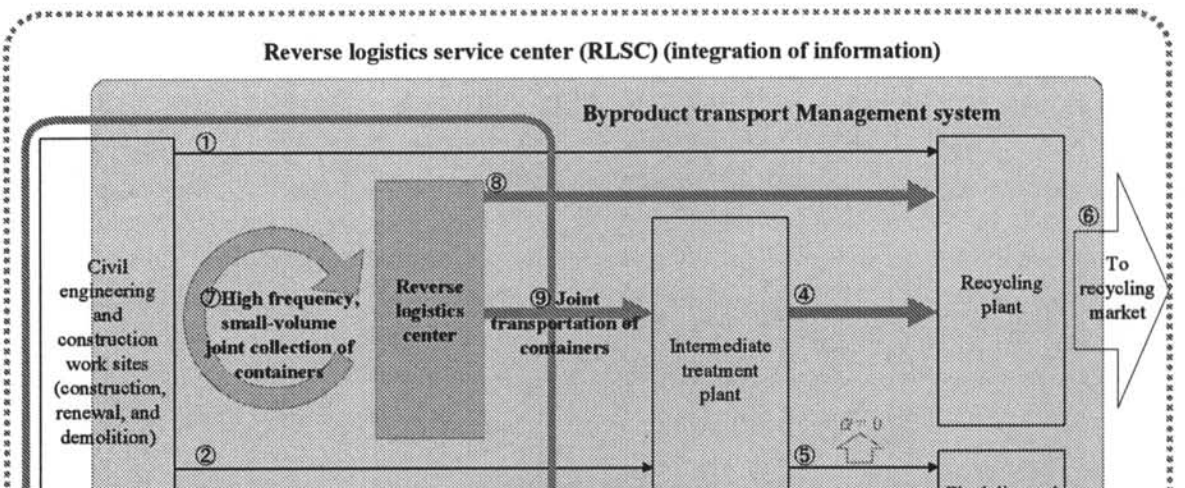

Fig. 3 Reverse logistics system design

The EDI (Electric Data Interchange) Joint Research Group, Asia Pacific Center, Waseda University, is currently making preparations for a September 2002 start of a demonstration test to verify the effectiveness of the reverse logistics system proposed in this research paper. It is the hope of the author that the operations reported in this paper will be able to contribute to the formation of an effective reverse industry.

Acknowledgment

It should be noted with the appreciation of the author that this research was conducted as part of the Harmony Project, one of projects carried out under the Intelligent Manufacturing System (IMS) Project sponsored by the New Energy and Industrial Technology Development Organization (NEDO).

References

1) Kazuhiro Ueda, Recycling Encyclopedia, Maruzen Publishing Co., Ltd., 2002, Feb., 25, pp.156-168

2) Hiroyuki Nakamura, et al. Material Transportation to and from Construction Site and its Cost Evaluation, J. Struct. Constr. Eng., AIJ, No. 529, pp. 203-210, 2000, Mar

3) Hiroyuki Nakamura, Construction Logistics System, 5th International Conference, Asia-Pacific Region of Decision Sciences Institute, 2000, July 24-27.

4) Hiroyuki Nakamura, et al. Inverse Distribution System of Construction for Closed-loop Construction System, Proc. of Ecodesign 2001: 2nd International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 2001, Dec. 11-15, Tokyo, Japan, pp. 696-701.

Appendix

[i] Quantity reduction by incineration: Incineration of organic wastes in order to decompose them into carbon oxide and water for discharge into the atmosphere. (Recycling Encyclopedia, Maruzen Publishing Co., Ltd.)