A Consideration on Design and Analysis of a Reverse Logistics Network System: A Case Study of Discarded Motor Vehicle Tires

Keizo WAKABAYASHI* and Kuninori SUZUKI*

(Received November 6, 2015)

Abstract

In this paper, we focus on discarded motor vehicle tires, and examine the possibility of constructing a reverse logistics network over a wider area and the integration or aggregation of logistical bases. This simulation includes a collection system algorithm and cluster-first/ route-second method, and we use local search. This procedure consists of three factors. The first is the collection of discarded tires and their transportation to factories as thermal fuels. The second is the improvement of the actual reverse logistics system for discarded tires. The last is the design of the improved reverse logistical system.

Key Words: Reverse Logistics, Thermal Recycle, Waste Management, Collection and Transport

1. Introduction

This study aims to analyze the present situation of collecting of discarded tires in a series of flows in a reverse logistics network and to simulate cooperative reverse logistics. Studies on forward logistics systems, including development, production, sales, and consumption of products, are now becoming remarkably advanced. However, studies on reverse chain logistics systems, including collection, transportation, intermediate treatment, recycling, and reuse of wastes, have not attracted as much attention from researchers. The present study is considered as a series of flows that include collection, intermediate treatment, and recycling of used automobile tires and the distribution of recycled products as a reverse chain.

2. Range of reverse logistics of discarded tires

The reuse of automobile tires (i.e., for discarded tires to be returned to tire markets as retreated tires after a recycling process) is currently eminently low. However, after collection from gas stations and wreckers, many discarded tires are given an intermediate treatment to convert to fuel chips, and the fuel chips are used in boilers in cement factories and paper and steel mills as a form of thermal recycling.

In 1994, Japan Automobile Tire Manufacturers Association (JATMA) unified the names of used tires into “discarded tires.” Since fuel chips are valuable materials, their transportation and distribution belong to forward logistics instead of the reverse logistics performed by collection and transportation enterprises. However, as the range of the forward supply chain of products is considered broadly overlapping that of the reverse
chain of wastes, this study adopts the idea that fuel chips belong to the area of reverse logistics.

A basic flow for discarded tires is as follows. When enterprises such as gas stations, tire dealers, and wreckers are sources of discarded tires, those are treated as industrial wastes. However, when collecting discarded tires for reverse logistics, a person in charge of these tires is obliged to present to reverse logistics at the collection point, and the collection is performed by a manifesto (industrial waste management sheet). Therefore, the time required for collecting discarded tires in reverse logistics tends to be longer than that required for distribution in forward logistics, in which tires are only delivered. Enterprises that collect and transport discarded tires must establish a collection plan on considering these matters. In the case where the same enterprise performs collection, transportation, and intermediate treatment of discarded tires, the enterprise must be engaged in the area of reverse logistics.

3. Outline of analysis and simulation of the actual state

Company A, which recycles discarded tires at Samukawa, Chigasaki, Kanagawa Prefecture, has licenses for collection, transportation, and intermediate treatment of discarded tires, and for transportation in forward logistics. The company recycles discarded tires into fuel chips, and it then sells to major paper and steel mills. Discarded tires are collected from tire dealers, auto wreckers, gas stations, and auto accessory stores in the Kanto district and then are converted into fuel chips at the company’s recycling factory. The Kanto district includes parts of Tokyo Metropolis, Chiba Prefecture, and Saitama Prefecture, centering on Kanagawa Prefecture.

4. Purpose of simulation analysis

Reproducing the actual situation of company A’s collection system for discarded tires and performing a scenario analysis of the future possibility of the collection system allows investigation of the present situation.

5. Outline of the simulation model

The simulation model used in this study is composed of three echelons: the collection complex, the transshipment and storage complex, and the intermediate treatment factory. Based on the management situation of company A’s collection system for discarded tires and conditions set for the scenario analysis, the following three desirable situations are investigated using a simulation model from the viewpoints of the environment, load, and cost of the entire collection system:

(a) Desirable situations of complexes (nodes) at each echelon.
(b) Desirable situation of movement (links) between complexes at the same echelon.
(c) Desirable situation of movement (links) between complexes at different echelons.

The actual investigation is performed as described below. Collection complexes at echelons located at the Collection sites, the upper part of Fig.1 (such as gas stations and auto accessory stores) are used as subjects, and the study investigates a collection device at each complex in the same echelon, a collection route between collection complexes, and routes to different echelons (such as provisionary storage and intermediate treatment factories). The provisionary storages belonging to echelons located at the center part of Fig.1 and the intermediate treatment factories including their elimination and consolidation at the bottom of Fig.1, for shifting to other intermediate treatment factories in the same echelon, for new establishment of a transshipment and storage complex, and for introduction of a modal shift between different echelons.

When the entire area of Chiba Prefecture is assumed to be the future collection area, establishing a transshipment and storage complex (temporary storage complex) in Chiba Prefecture and performing batch transportation between the temporary storage complex and an intermediate treatment factory in Kanagawa Prefecture may be more efficient than consolidating collection complexes into one or two in Kanagawa Prefecture and performing real-time collection. Fig.1 also shows conditions for these complexes.

For example, there are the collection frequency, collection amount, type of vehicle used for collection, existence of transshipment and storage complex, identification of intermediate treatment factory, time window,
6. Algorithm and preconditions for simulation

A simulation model used for the collection system of discarded tires consists mainly of routes between collection complexes, such as gas stations. An algorithm for allocating vehicles in forward logistics is used to create an algorithm suitable for the collection system. To create the algorithm, the use of an algorithm appropriate to the cluster-based routing algorithm is considered. The collection plan is established based on the following 6 steps:

Step 1: Select a store (collection point) such as gas station, which has the most remarkable problem in allocating vehicles, such as geographically distant location.

Step 2: Evaluate the existence of an efficient route between collection points, which satisfies the predetermined conditions, after adding a collection point nearest to the selected collection point.

Step 3: Confirm that the predetermined conditions are satisfied after adding the second-nearest point, when the predetermined conditions have been satisfied in Step 2.

Step 4: Evaluate the second-nearest point after excluding the point nearest to the selected collection point, when the predetermined conditions have not been satisfied in Step 2.

Step 5: Determine a route for the selected store after performing Steps 1–4 on all stores.

Step 6: Determine routes for remaining stores by performing Steps 1–4, after determining the route in Step 5.

---

Fig.1 Setting of echelons for motor vehicle tires recycle system ①
The method to determine an efficient route is first to extract a route, which can be expected to be the geometrically shortest, from Hamilton circuits connecting stores to be travelled. Subsequently, the method improves the extracted route by a local search. The predetermined conditions, which should be considered in the collection of discarded tires, are summarized as follows:

(a) For collecting discarded tires, 4-ton trucks are used and boxes filled with discarded tires are exchanged for empty boxes at gas stations and tire dealers.
(b) 4-ton trucks loading empty boxes leave from two reprocessing factories and return to the same factories after collecting discarded tires.
(c) Distribution and exchange of boxes and collection of discarded tires must be performed.
(d) One 4-ton truck performs both collection of discarded tires and exchange of boxes.
(e) Discarded tires exceeding the capacity of a 4-ton truck are allowed to stay at the collection points.

7. Outline of data on collection points

At present, company A has 150 collection points for discarded tires in the Kanto district, with a central focus on Tokyo Metropolis and Kanagawa Prefecture.

In the future, the company will introduce a cooperative collection system and extend the collection area, concentrating on Chiba Prefecture. Assuming an increase in the number of collection points as in Fig.2, the data on potential collection points are prepared in addition to the data of existing collection points. Here, potential collection points means the company’s prospective customers in the near future, in addition to the collection sites which the company currently runs.

8. The number of collections and travel distance

According to the numerical results from the computer simulation, as Table 1 shows, the number of collection points that a vehicle could visit was restricted by the time required for the travel and the number of discarded tires. In the case where a certain number of collections were fixed, the number of vehicles was not affected by the number of collection points.

Nevertheless, It was revealed that a reduction effect was seen because long-distance collection became by increasing bases about the mileage.

For example, in the case of 150 collection sites, 25 trucks, 6.1 collection sites by truck on average, 88 tires

Fig.2 Potential collection site
per one truck, 88% for loading percentage, and 163km for total distance can be found, while 32 trucks, 6.4 collection sites by truck on average, 92 tires per one truck, 92% for loading percentage, and 150km for total distance can be found in the case of 394 collection sites. That is to say, the improvement measure shows 8% of reductions for its performance.

9. Conclusion

This study used actual data for the collection system of discarded tires to perform a simulation clarified the actual state of the collection system, pointed out problems and that found out the efficiency of reverse logistics was reduced. When a model for the consolidation of distribution complexes, which has been an effective tool to improve the distribution efficiency in forward logistics, was directly applied to reverse logistics, the expected results were not realized, because the time required for tasks at the complexes is longer in reverse logistics than in forward logistics.

For the solution to minimize the tasks at the complexes, Company A considers the introduction of removable containers for collecting discarded tires at some collection points. The future issues should be detailed its examinations for the effect of the removable container on the collection efficiency.

This study analyzed and simulated the present and possible situations for collection of discarded tires in a series of flows in a reverse logistics network, even if the expected results were not realized. As mentioned above, for the solution, further study will consider on introduction of removable containers for collecting discarded tires at some collection points.

10. References

リバースロジスティクスネットワークシステムの設計及び分析
——自動車の廃タイヤを事例として——

若林 敬造, 鈴木 邦成

概 要

廃タイヤの回収に関する一連の配送プロセスについて効率化策を提案しシミュレーション分析を行う。廃タイヤはガソリンスタンドなどの店舗から回収され、中間処理工場で生産される廃タイヤ由来の燃料チップは製紙工場、製鉄所、セメント工場などに有価物として配送される。廃タイヤ回収プロセスにおける効率化を考察するべく、関東エリアの回収網を再現し、その現状と課題を探り出すことにする。
Biographical Sketches of the Authors

Keizo Wakabayashi is a professor, Department of Industrial Engineering and Management, College of Industrial Technology, Nihon University. He received his Ph. D degree in Industrial Engineering from Hokkaido University. His research interests are in area of logistics systems and supply chain management systems. He is Chairman of The Japan Society of Logistics Systems (JSLS), and Vice Chairman of The International Federation of Logistics and SCM Systems (IFLS).

Kuninori Suzuki is a professor, Department of Industrial Engineering and Management, College of Industrial Technology, Nihon University. He received Dr. of Engineering from Nihon University. His research interests are in area of both forward and reverse logistics systems, and its information systems. He is a member and manager of The Japan Society of Logistics Systems (JSLS). He is Managing Director of The International Federation of Logistics and SCM Systems (IFLS).