A MODAL SHIFT FROM TRUCKS TO RAILWAY AND MARINE TRANSPORT IN JAPAN

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ABSTRACT

In this paper, we discuss the possibility of a shift from road to railway and marine transportation between the Tokyo metropolitan area and the remote areas of Japan by analyzing the behavior of cargo shippers and we clarify the factors involved in the choice of transport mode by transport distance, time, cost, freight lot size and other related factors. The analysis procedures were conducted using logit models.

As a result, factors influencing the modal choice could be identified and we found that a considerable portion of currently existing transportation could be converted to container transport by ships and rail. We investigate the influence on modal split on changes in transport cost and freight lot size by means of sensitivity analysis. Finally, we estimate the CO_2 emission reduction for changes in transport cost.

INTRODUCTION

Various action plans have been put together to achieve the Kyoto Protocol's targets for the reduction of greenhouse gas emissions. A modal shift from trucks to rail and marine transport is considered a means to this end. However, the rail and vessel shares of total shipments are in a state of continuing decline.

In this paper, we discuss the possibility of a modal shift from road to railway and marine freight transport between the Tokyo metropolitan area and distant areas like Hokkaido, Tohoku and Kyushu, by analyzing the behavior of cargo shippers. Using statistics on physical distribution data for the year 2000, we clarify the factors involved in the choice of type of transport modes by transport distance, time, cost, freight lot size and other factors. These analytic forms were conducted by means of logit models. This model is a probabilistic model for representing the discrete choice/behavior of individuals. The individual is assumed to behave as though a choice of alternatives had been considered in a hierarchical manner. Based on the information collected from meetings with businesses and questionnaire responses from cargo shippers, we also studied existing barriers to change and potential solutions that could advance the shift to railway and marine transports.

As a result, factors influencing the modal choice could be identified and we found that a considerable portion of total transportation can be converted to container transport by ferry ships and railway. In addition, we estimated the feasible scale of this shift. The greater the increase in rail and marine transports, the more loading efficiency would improve, and this in turn would lead to a reduction in CO_2 emissions. We investigated the influence on modal

split of changes in transport cost and freight lot size by using sensitivity analysis. Finally, we show the CO_2 emission reduction brought about by changes in transport cost.

LOGIT MODELS

In this study, we built logit models for freight traffic to estimate cargo owner behavior and we apply these models to predict the modal split between the road traffic and railway containers and also between the trucks and ferry traffics for each relevant origin-destination pair. The models used the assumption that a cargo owner would choose the mode offering the maximum benefit to the firm, a factor that can be measured by utility. The basic principle of the logit model is that people behave rationally: they are constantly trying to maximize their utility. This utility can be described with a utility function, which is divided into two components: strict utility and a stochastic element. The higher the utility, the more likely that alternative will be chosen. The models are also used to test effects of some policies related to the development of freight transportation systems.

A disaggregate model such as a logit model is based on individual behaviour. Therefore it takes into account important characteristics of the decision-maker that make possible a richer model specification. A better understanding of intermodal competition is accomplished due to the fact that these models use the actual attributes of modes and characteristics of the goods to be transported for generating estimates. The principal limitations of disaggregate models are the considerable amount of data required, difficulties compiling this data on individual mode choices and the complexity of defining all attributes that determine choice. Fortunately, we could obtain data using a three-day-survey collected from the 7th Physical Distribution Census that was carried out in fiscal year 2000. These data are based on the origin-destination zones divided into 227 areas by mode.

The probability of choosing freight mode *i* in logit model can be expressed as follows.

$$P_{in} = \frac{\exp(V_{in})}{\exp(V_{in}) + \exp(V_{jn})} \tag{1}$$

$$V_{in} = \sum \theta_{ki} a_{kn} \tag{2}$$

where P_{in} is the probability of choosing mode *i* by item *n*, θ_{ki} is a parameter for explaining variable *k*, a_{kn} explains variable *k* of item *n*, V_{in} is utility which is obtained by mode *i* of item *n*.

The targeted transport modes are the consolidated freight truck freight services, such as parcel delivery service, and the chartered trucks for the road traffic, railroad containers and ferry service ships. The models identify the possibility of choosing a mode combining trucks and railway container and combining trucks and ferries for freight traffic between the Tokyo metropolitan area and the remote areas of Japan (Hokkaido, Tohoku and Kyushu area).

Table 1 shows the targets used by logit models. The explanation variables considered for the logit models included the following: access time and distance from origin of shipment to the nearest freight station or port used for the mainline transport, trunk time and distance for mainline transport; egress time and distance from the cargo station or port in destination area

Table 1. Logit models

Model	Freight Transport	Modal Choice
1	Hokkaido, Tohoku ⇔ Tokyo metro	Truck and railway container
2	Hokkaido ⇔ Tokyo metro	Truck and ferry ship
3	Kyushu ⇔ Tokyo metro	Truck and railway container
4	Kyushu ⇔ Tokyo metro	Truck and ferry ship

Table 2. Explanation variables, parameters and *t*- values

Explanation variable	Parameter and *t*- value			
	Model 1	Model 2	Model 3	Model 4
Access Time	-0.0537 (-5.23)	-	-0.109 (-4.17)	-0.949 (-4.93)
Total Time	-	-0.0322 (-3.27)	-	-
Transport Cost	-0.00818 (-8.44)	-0.00377 (-2.85)	-0.00255 (-5.22)	-0.00499 (-7.91)
Log Lotsize	1.35 [train] (11.8)	-	1.24 (11.7)	1.18 (9.74)
Correction term	-3.59 [train]	-3.26 [track]	-1.65 [train]	-2.01 [train]

( ) is *t*-value [ ] is target

Table 3. Hit ratios and likelihood ratios

	Model 1	Model 2	Model 3	Model 4
Track hit ratio	0.72	0.58	0.81	0.81
Railway hit ratio	0.85	-	0.69	-
Ferry hit ratio	-	0.62	-	0.79
Average hit ratio	0.79	0.60	0.76	0.80
Likelihood ratio	0.37	0.08	0.27	0.32

to place of arrival. Also included were total time and distance between origin and destination places; transportation cost, and freight lot size (logarithmic value). Appropriate variables were selected from these variables based on the results of model applications.

RESULTS OF APPLICATION OF LOGIT MODELS

A software program, LIMDEP/NLOGIT, was used to calculate results using this model analysis. The analysis was conducted for the four models, respectively. Table 2 shows the explanation variables selected for these models and their parameters and *t*-values. Table 3 shows the hit ratios and likelihood ratios.

From these results, we found that the factors influencing mode choice were the freight lot size of the goods, transport cost and the total transport time between the origin and destination areas, and access time to the nearest port or cargo station.

Freight lot size is an especially significant determinant of mode choice related to transportation between Tokyo and Kyushu area, whereas transport cost is a common

significant determinant of mode choice for all areas. These factors have an influence on the selection ratio of a mode. The larger the lot size of the freight and the less the transport cost by railway and ferry, the more the share of railway and ferry containers.

SENSITIVITY ANALYSIS

We also conducted some sensitivity analyses based on the results of the applications. We first investigated the influence on modal split of changes in transport cost and freight lot size in the case of cargo shipped from Hokkaido, Tohoku or Kyushu to Tokyo.

As the freight lot size increases, the probabilities of choosing railway container and ferry ships versus trucks in logit model are shown in Figure 1 and 2. In the same way, possibilities of choosing railway container and ferry ships versus trucks when the transport costs by railway and ferry decrease are shown in Figure 3 and 4. It can be seen that the influence of freight lot size is relatively large and this factor is crucial for the modal shift from road traffic to railway or ships.

CO_2 EMISSION REDUCTION RATES

When transport costs by railway and ferry decrease, we can estimate the CO_2 emission reduction rates that can be derived from the transport volume, the CO_2 emission coefficients

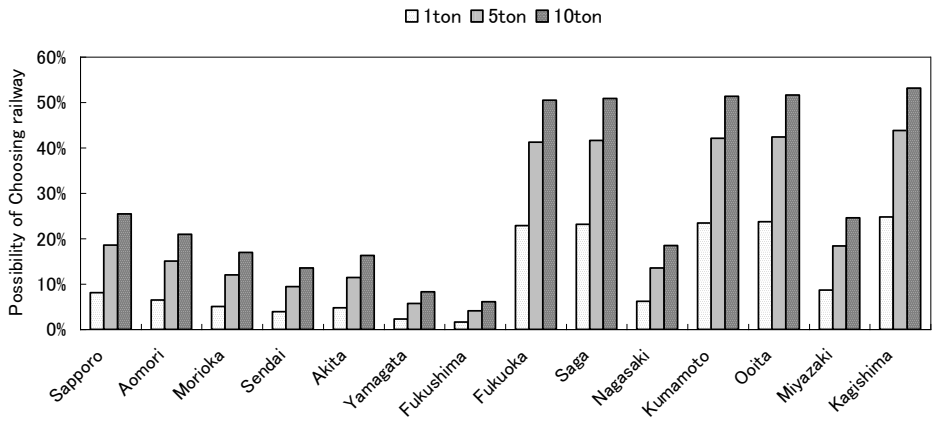

Fig 1. Possibilities of choosing railway versus trucks, increasing lot size

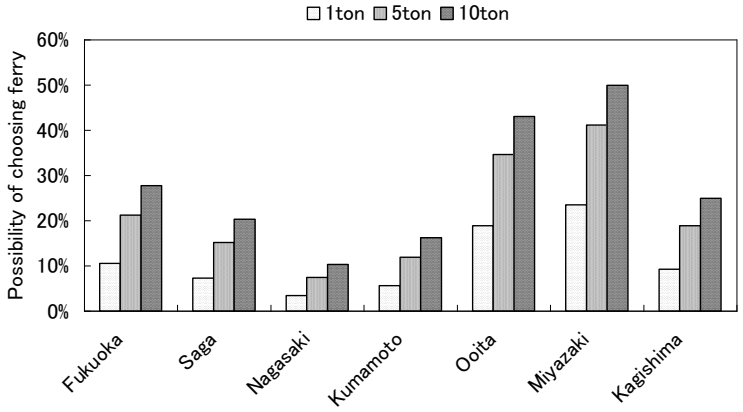

Fig 2. Possibilities of choosing ferry versus trucks, increasing lot size

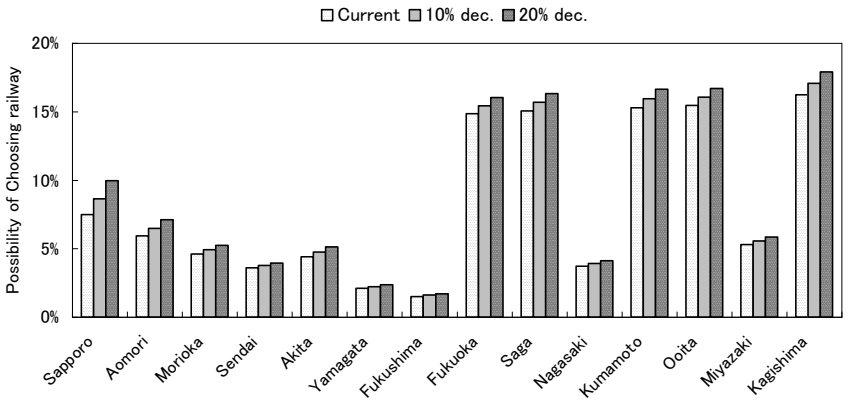

Fig 3. Possibilities of choosing railway versus trucks, decreasing cost

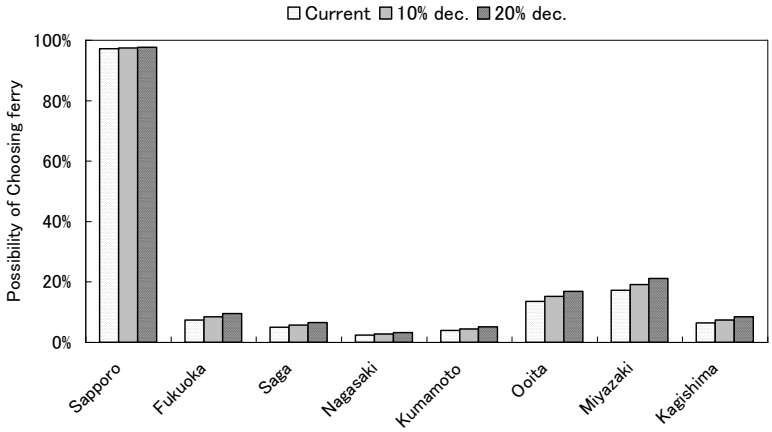

Fig 4. Possibilities of choosing ferry versus trucks, decreasing cost

and changing rate for the probabilities of choosing railway container and ferry ships versus trucks based on the logit models. Table 3 shows the CO_2 emission coefficients for each transport mode. The CO_2 emission reduction rates for the freight from each prefecture to the Tokyo metropolitan area when transport costs decrease 10 and 20 percent are shown in Figure 5 and 6.

CONCLUSIONS

In this paper, we discussed the possibility of a modal shift from road to railway and marine transports between the Tokyo metropolitan area and the remote areas of Japan by analyzing the behavior of cargo shippers. We clarified the factors involved in the choice of transport mode by transport distance, time, cost, freight lot size, and so on. These analyses were conducted using logit models.

Table 3. CO_2 emission coefficients
(2000 year, g- CO_2/ton・km)

Commercial trucker	178
Small-size commercial trucker	819
Private truck	372
Small-size private truck	3,049
Railway	21
Ship	40
Air	1,483

Results of the statistical analyses showed that factors influencing on the modal choice

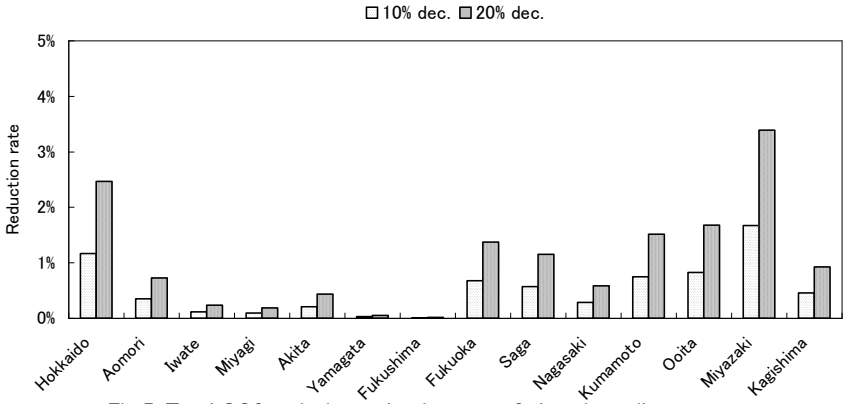

Fig 5. Total CO2 emission reduction rate of choosing railway versus trucks, decreasing cost

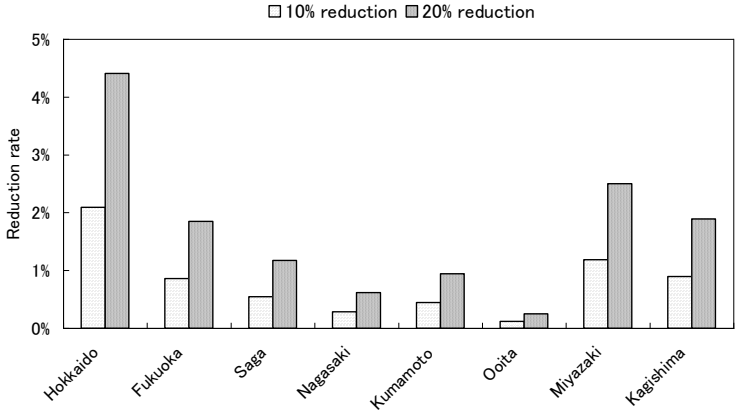

Fig 6. Total CO2 emission reduction rate of choosing ferry versus trucks, decreasing cost

could be identified and we found that a considerable portion of freight could be converted to container transport by ships and rail. Significant factors for the modal shift were freight lot size, access time to the nearest cargo station or port, total time between origin and destination areas and transport cost.

We also investigated the influence on modal split of changes in transport cost and freight lot size by means of sensitivity analysis. We found that when the freight lot size by railway or ferry increases, modal shift from trucks to railway or ferry accelerate, especially in the case of large-scale mainline freight transport. Finally, we estimated the CO_2 emission reduction rate when transport cost decrease, and analyzed the environmental impact of the modal shifts from road to railway and marine transports.

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