The Influence of Railway Freight Transport on Logistics Costs

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The majority of the costs involved in logistics come from freight transport expenses, which are affected by various factors in today's world of economic deregulation. This study seeks to investigate the effectiveness of railway freight as a way of controlling logistics costs under the current conditions faced by major shippers. Models to express the composite mechanism of truckload freight rates (i.e., transport expenses per ton-kilometer) based on a mileage system are introduced to enable case analysis. The suitability of each model and the availability and explanatory power of each constituent factor are then discussed in details. Finally, the degree of influence on the logistics expenses incurred by shippers using railway freight transport is derived.

Keywords: logistics costs, influence of railways, truckload transport, freight rate

1. Introduction

With the development of socio-economy and the completion of Japan's transport network, the regulative background of the freight transport industry has changed drastically. The country's truckage system has a historical transition from requiring prior governmental approval under the Road Transport Law in 1951, to one that requires prior notification according to two logistics-related laws, i.e., Truck Freight Transport Business Law and Freight Transport Handling Business Law, in 1990, to posterior reporting system established through the revision of these logistics-related laws, i.e., revised Truck Freight Transport Business Law and revised Freight Transport Handling Business = Law Freight Transport Forwarder Business Law, in 2002 [1]. In fact, it is legal for transport carriers to freely decide the transport expenses they wish to charge.

However, the economic deregulation of the freight transport market has brought significant changes to the freight charge system. Competition in the market has grown considerably, and has become increasingly fierce due to the abolition of operating-zone restrictions and supply-demand adjustment rules. In the industry today, freight rates and relevant charges are generally determined through negotiation between the carriers and the shippers involved. Shippers frequently take the initiative in the process of setting freight transport expenses, although the charges can be freely decided by the carriers according to the applicable laws. Recent investigative reports have analyzed these changes in the field of logistics, as referred in [2] and [3]. In addition, the effects of economic deregulation on surface freight transport were also studied in [4].

In this paper, the constituent factors influencing truckload freight rates based on a mileage system are first described under the current conditions of the logistics market. Then, by way of case analysis, models to explain the structural mechanism of truckload freight rates are built according to actual survey data from major shippers. The suitability of the models and the explanatory power of each factor are also discussed in details. Finally, the degree of influence on the logistics costs incurred by shippers using railway freight transport is derived.

2. Constituent factors of truckload freight rates

Although freight carriers can freely set transport expenses according to legislation, in reality they are almost wholly determined through negotiation between the carriers and the shippers. Shippers usually take the initiative in the procedure, and therefore often consider the following influence factors when choosing a freight transport carrier or mode.

2.1 Type of freight transport

According to the actual conditions of truck freight transport, the relevant freight types and charges can be roughly divided into seven categories: (i) mixed loading fees, (ii) home-delivery fees, (iii) mail service fees, (iv) truckload fees, (v) removal fees, (vi) special freight fees and (vii) transport fees charged by the forwarder. The framework of the various fees, which are generally determined according to weight and shipment distance, must be comprehensible to shippers. The calculation method for each type can be described as outlined below.

In Case (i), a “per lot” or “per piece” system corresponding to weight or cubic content and distance or zone is used in principle. Case (ii) is for freight weighing 30 kg or less, and a “per piece” system is adopted in principle based on (i). In addition, the system for case (iii) is for lighter freight based on (i). Cases (iv), (v) and (vi) are governed by a system of truckload transport corresponding to distance or time in principle. Truckload transport fees and charges therefore generally involve systems that set pricing based on time and distance.

Shippers often choose one or more types of freight and transport means according to the lot size, weight, cubic content, etc. of the shipment in line with market conditions. Actual trucking results from the logistics surveys

2.2 Relationships between shippers and transport carriers

Major Japanese manufacturers tend to have in-house logistics departments, and most shipping companies have a logistics subsidiary within their business group. The majority of these companies play the role of primary contractor in the freight transport industry. Large amounts of freight are also moved by transport companies affiliated to haulage contractors and general trucking companies.

2.3 Contract term

There are various types of contract term, which are determined by negotiation between carriers and shippers. Contracts include long-term agreements lasting over two years as well as those that last a year, six months or even just a few months.

2.4 Use of expressways or ferries

When a shipper engages a carrier for transport, the fees involved are often set differently depending on whether expressways or ferries are used.

2.5 Use of railway freight

It is advantageous for shippers to have more than one means of transport available. Marine transport is often considered for transporting bulky raw materials within Japan. Railways are also effective as a means of mass transport for industrial products and components, and some special materials in surface freight. Shippers therefore tend to have the upper hand in freight negotiation with carriers.

2.6 Transport distance and truck tonnage

Since 1971, the setting of truckload fees has been based on a “freight by truckload” system, which includes mileage and time systems. Most time-based charges are limited to freight distribution in urban and suburban areas. In freight transport over intermediate or long distances, a mileage-based freight rate system is often used.

3. Compositional mechanism modeling of truckload rates based on a mileage system

Thus far, the relevant factors influencing freight fees were analyzed. It is necessary to consider how these factors affect actual fee settings. Although there is a need to analyze the mechanism of the various costs involved due to the diversity of fees in today’s trucking industry, this study focuses on mileage system fees and investigates the mechanism of truckload transport rates using actual data from the survey results of [5] and [6].

3.1 Formulation to express the compositional mechanism of truckload freight rates

The main factors involved in the setting of truckload freight rates based on a mileage system are the truck type (i.e., the tonnage) and the transport distance. The conventional tariff based on a ton-kilometer freight rate generally tends to decrease with increased transport distance and/or vehicle tonnage.

In reality, as stated previously, many factors influence truckage. When a shipper chooses a carrier to transport freight, the whole range of carriers available is generally considered. Charges involved in using expressways or ferries if necessary, as well as the term of the contract with the carrier, have an influence on freight rates. In addition, when multiple means of transport are available, shippers have the advantage in transport contract negotiations with carriers.

Accordingly, the mechanism formula outlined below is considered for truckload freight rates based on a mileage system. It is a complex formula based on the Cobb-Douglas production function and an exponential function. The Cobb-Douglas function is a basic tool to express the fundamental relationship between the freight rate and the transport distance/truck type. The exponential function represents other factors of influence.

\[
c = f(X_1, X_2, X_3, X_4, X_5, X_6) = \alpha X_1\beta X_2 \exp(\beta_1 X_3 + \beta_2 X_4 + \beta_3 X_5 + \beta_4 X_6)
\]

where

- \(c\) = Freight rate of a charter truck based on a mileage system (yen/ton-km);
- \(X_1\) = Transport distance (km);
- \(X_2\) = Truck tonnage (tons);
- \(X_3\) = Dummy variable to represent the status of railway use (used: 1, not used: 0);
- \(X_4\) = Dummy variable to represent the status of expressway or ferries use (used: 1, not used: 0);
- \(X_5\) = Fuzzy membership function to represent the characteristics of the truck transport company;
- \(X_6\) = Contract term (year);
- \(\alpha, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6\) = Parameter of each factor estimated using actual data from shippers.

3.2 Fuzzy membership function to represent the characteristics of carriers

Truck carriers can be roughly classified into the five types outlined below according to the current characteristics of carriers in the logistics industry.
1) Shippers’ own logistics departments: Many major shippers, such as large manufacturers, have their own logistics departments that transport self-freight using private trucks or as primary contractors.
2) Subsidiary companies: The group companies of shippers may include subsidiary transport firms that play a role in corporate freight transport.
3) Affiliate trucking companies: Trucking companies affiliated to the business group of a shipper tend to be more independent in business than subsidiaries.
4) Dedicated trucking companies: This kind of carrier usually provides exclusive transport services for spe-
cific shippers.

5) General trucking companies: These companies offer freight services to all shippers. In reality, shippers often simultaneously use multiple carriers to meet different transport needs. The characteristics of these trucking companies can be quantitatively expressed through the distance fuzzy membership function concerned, as defined by the connection (known as the relations distance) between shippers and carriers. As a general tendency, a weaker connecting relationship be-

![Fig. 1 Fuzzy membership function to represent the characteristics of trucking companies](image)

<table>
<thead>
<tr>
<th>Table 1 Compositional mechanism models of truckload rates in a mileage system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variable (constituent factor)</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>$X_t$ (Transport distance)</td>
</tr>
<tr>
<td>$X_t$ (Truck tonnage)</td>
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<td></td>
</tr>
<tr>
<td>$X_t$ (Use of railway: dummy variable)</td>
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<td></td>
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<tr>
<td>$X_t$ (Use of expressway or ferries: dummy variable)</td>
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<td></td>
</tr>
<tr>
<td>$X_t$ (Characteristics of trucking companies: fuzzy membership)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>$X_t$ (Transport contract term)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Constant item</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Coefficient of correlation R</td>
</tr>
</tbody>
</table>
tween the shipper and the trucking carrier means a greater distance fuzzy membership. In order to describe the characteristics of trucking companies quantitatively, a linear fuzzy membership function is therefore introduced elsewhere as shown in Fig. 1. By way of example, if the logistic department of the shipper is used, the fuzzy membership is zero, and for a general trucking company the fuzzy membership is 1.0.

3.3 Case studies using compositive mechanism models

Models can be built to express truckload freight rates according to different case analyses with changes in constituent factors based on (1).

1) Case study 1: This is a fundamental model of the truckload rate; only the transport distance and vehicle tonnage, the most basic constituents of the freight rate, are included:

\[ c = f(X_1, X_2) = \alpha X_1^\beta_1 X_2^\beta_2 \]

2) Case study 2: Based on case study 1, the use of expressways or ferries in truck freight transport is considered as a constituent of the freight rate:

\[ c = f(X_1, X_2, X_3) = \alpha X_1^\beta_1 X_2^\beta_2 \exp(\beta_3 X_3) \]

3) Case study 3: The fuzzy membership function to describe the characteristics of the trucking company and the contract term are considered as constituents in addition to case study 2:

\[ c = f(X_1, X_2, X_3, X_4, X_5, X_6) = \alpha X_1^\beta_1 X_2^\beta_2 \exp(\beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6) \]

4) Case study 4: All the constituent factors mentioned previously that may influence the truckload freight rate are used to construct the model shown in (1), that is:

\[ c = f(X_1, X_2, X_3, X_4, X_5, X_6) = \alpha X_1^\beta_1 X_2^\beta_2 \exp(\beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6) \]

5) Case study 5: For comparative analysis, speculation on the use of railways and expressways/ferries by shippers is brought into this case study, in which only dummy variables representing the railway and expressway or ferries use are available based on case study 1:

\[ c = f(X_1, X_2, X_3, X_4, X_5, X_6) = \alpha X_1^\beta_1 X_2^\beta_2 \exp(\beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6) \]

Using actual data on freight transport expenses from shippers [5],[6], relevant models for the truckload freight rate corresponding to different cases can be built using regression analysis. The results are given in Table 1, in which each parameter of the constituents in the different case studies is estimated. The t-value corresponding to the parameter of each constituent factor is a test statistic indicating the suitability of each parameter value estimated. The lowermost part of the table gives the correlation coefficient for each model.

<table>
<thead>
<tr>
<th>Explanatory variable (Constituent factor)</th>
<th>Parameter</th>
<th>Scope of</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>X₁ (Transport distance)</td>
<td>β₁</td>
<td>t-value</td>
<td>&gt; 66</td>
</tr>
<tr>
<td>X₂ (Truck tonnage)</td>
<td>β₂</td>
<td>t-value</td>
<td>&gt; 69</td>
</tr>
<tr>
<td>X₃ (Use of railway: dummy variable)</td>
<td>β₃</td>
<td>t-value</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>X₄ (Use of expressway or ferries: dummy variable)</td>
<td>β₄</td>
<td>t-value</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>X₅ (Characteristics of trucking companies: fuzzy membership)</td>
<td>β₅</td>
<td>t-value</td>
<td>&lt; 1.96</td>
</tr>
<tr>
<td>X₆ (Transport contract term)</td>
<td>β₆</td>
<td>1.96 &lt;</td>
<td>t-value</td>
</tr>
<tr>
<td>Constant item</td>
<td>α</td>
<td>t-value</td>
<td>&gt; 154</td>
</tr>
</tbody>
</table>

Table 2 Availability of constituent factors in the truckload freight rate
4. **Analysis of reliability and availability for the estimated models**

4.1 **Reliability of the mechanism models estimated**

The fundamental index to indicate the reliability of the mechanism models estimated is the coefficient value of correlation, i.e., values of correlation coefficient $R$ that are closer to 1.0 indicate a higher level of reliability in the estimated model for expressing the truckload freight rate. Table 1 shows that all the estimated models have higher reliability, because their correlation coefficient values exceed 0.9.

4.2 **Availability of constituent factors of the truckload freight rate**

The availability of each constituent factor in the truckload freight rate is often estimated from the absolute value of the relevant test statistic (i.e., the t-value) for the estimated parameters of the main variables. Generally, if the t-value is greater than 2.58, the relevant constituent factor has an availability with a 1% level of significance. If the absolute t-value is greater than 1.96, the availability of factors with a 5% level of significance can be estimated. Of course, the greater the absolute t-value of the parameter, the more significant the availability of the relevant factor.

Table 2 shows the results of availability analysis on the factors of each estimated model used to express the truckload freight rate. The table indicates that the constituent factors of the truckload freight rate (such as the transport distance, the truck tonnage and the use of railways/expressways/ferries) demonstrate significant availability with a 1% test level, as all their absolute test statistic values are much higher than 2.58. The factor of transport contract term has availability with a 5% level of significance because the relevant absolute t-value is greater than 1.96 and less than 2.58. Theconstant item also has higher availability in all the case studies, as its t-value in each case is greater than 154.

As to the characteristics of trucking companies, availability in the truckload freight rate as a constituent factor is not shown because the relevant absolute t-value is 0.222 for case model 3 and 0.194 for case model 4, which is much smaller than 1.96 with a 5% level of significance. It is necessary to analyze the characteristics of trucking companies in future research.

4.3 **The influence of constituent factors**

The extent to which the constituent factors influence truckload freight rates is indicated by the value of the relevant parameter ($\beta_i$). Of course, the greater the absolute value of the relevant factor's parameter, the stronger the factor's influence on the truckload freight rate.

In the mechanism models of truckload freight rates presumed above, it is found that even if there are changes in the model contents, the parameter values of the variables to express the transport distance and truck tonnage do not fluctuate greatly. It is confirmed that these variables are both still fundamental factors in deciding truckload rates. The value of the parameter ($\alpha$) of the constant term changes with variations in the relevant model's con-

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**Table 3: Influence of constituent factors on truckload freight rates**

<table>
<thead>
<tr>
<th>Explanatory variable (Constituent factor)</th>
<th>Absolute value of parameter</th>
<th>Influence of constituent factors</th>
<th>Case model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$ (Transport distance)</td>
<td>$</td>
<td>\beta_i</td>
<td>&gt; 0.37$</td>
</tr>
<tr>
<td>$X_2$ (Truck tonnage)</td>
<td>$</td>
<td>\beta_i</td>
<td>&gt; 0.60$</td>
</tr>
<tr>
<td>$X_3$ (Use of railway: dummy variable)</td>
<td>$</td>
<td>\beta_i</td>
<td>&gt; 0.06$</td>
</tr>
<tr>
<td>$X_4$ (Use of expressway or ferries: dummy variable)</td>
<td>$</td>
<td>\beta_i</td>
<td>&gt; 0.08$</td>
</tr>
<tr>
<td>$X_5$ (Characteristics of trucking companies: fuzzy membership)</td>
<td>$</td>
<td>\beta_i</td>
<td>&lt; 0.007$</td>
</tr>
<tr>
<td>$X_6$ (Transport contract term)</td>
<td>$</td>
<td>\beta_i</td>
<td>&lt; 0.004$</td>
</tr>
</tbody>
</table>

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tents, showing that there are other influential factors at work besides the transport distance and truck tonnage. It is therefore also necessary to discuss the influence of each constituent factor on truckload freight rates.

Table 3 shows the degree of influence of each constituent factor on truckload rates in the case models estimated. As basic factors, the transport distance and truck tonnage have a strong influence on freight rates because the absolute values of parameters ($\beta_1$) and ($\beta_2$) are greater than 0.3 and 0.6, respectively, in all models. The models estimated also demonstrate that the truckload freight rate gradually decreases with rising transport distance and truck tonnage.

A dummy variable to represent the condition of shippers using railways is introduced in model 4 and 5. The absolute values of its parameters ($\beta_3$) are both greater than 0.06, so it can be derived that using railways also has some degree of influence on truckload rates when shippers want to transport freight. Since the parameter is negative when shippers use railways for freight transport in conjunction with truck transport, the relevant truckload freight rate is reduced. This phenomenon explains the mutual impact that different means of transport have on each other.

The dummy variable to represent the use of expressways/ferries in freight transport is included in model 2, 3, 4 and 5. The values of the relevant parameter ($\beta_4$) in each model are 0.1, 0.097, 0.087 and 0.09, respectively. It therefore turns out that the use of expressways/ferries by shippers has a considerable positive influence on the freight rate because of the positive parameter value ($\beta_4$).

Moreover, for the variable to explain carrier company characteristics, the relevant parameter value shows that the logistics costs incurred by shippers can be reduced if they select freight transport through outsourced carriers with fewer business relations. Logically, the variables of model 3 and 4 closely reflect the trend of shift from private to business trucks in today’s freight transport industry, although the relevant parameter values are only −0.007 and −0.006, respectively.

Similarly, as competition in the freight transport business has become more serious in recent years, contract terms between shippers and carriers are becoming shorter to allow the reduction of logistics costs. The variables for the contract term in model 3 and 4 reflect this tendency. According to these models, the rates for contracted freight several years ago were comparatively high. Although the relevant estimated parameter values in model 3 and 4 (i.e., 0.004 and 0.003, respectively) demonstrate this, the influence of this factor on truckload freight rates is weaker.

5. Investigation of the influence of railway freight on logistics costs

The degree of influence exerted by the use of railway freight transport on logistics costs is further investigated here. The focus is how much the relevant truckload freight rate is reduced due to the influence of railways when shippers adopt railway freight transport in conjunction with a main policy of using truck-based freight transport.

Figure 2 shows the results of computing the truckload freight rate based on a mileage system with and without the use of railways for freight transport. It shows that transport distance and truck tonnage are still fundamental factors in deciding the truckload freight rate, which decreases in line with increases in these values. The figure also shows the degree of influence that railways exert on logistics costs by comparing truckload freight rates for the use of truck transport with and without the simultaneous use of railways.

Based on the above discussions, in the same way as transport distance and truck tonnage, the influence exerted by railways on logistics costs can be calculated using (2).

$$\Delta c = \frac{c - c'}{c}$$  \hspace{1cm} (2)

where

$\Delta c =$ Degree of influence of railways on logistics costs; 
$c'$ = Truckload freight rate based on a mileage system.
when shippers also use railways for freight transport simultaneously;

\[ c'' = \text{Truckload freight rate based on a mileage system} \]

when shippers do not use railways for freight transport simultaneously.

The relevant calculation shows that using railways in conjunction with truck transport to shift freight reduces the truckload freight rate by about 6%.

This finding indicates that railway freight transport still has a considerable influence on logistics costs, even though truck transport controls the logistics market for surface freight.

**6. Conclusion**

Under the current conditions of economic deregulation and severe competition in the freight transport market, the freight rate for truckload transport is fundamentally set through negotiation between shippers and carriers. In order to reduce logistics costs, shippers often consider the multiple factors involved when choosing carriers and means of transport, and simultaneously use different means for their freight. A mutual influence among carriers and/or transport modes therefore applies in setting transport expenses.

This paper focuses on the analysis of truckload freight rates to investigate the influence of railway freight as a constituent factor in addition to the transport distance and vehicle tonnage. A compositive mechanism to explain truckload freight rates was systematically analyzed, and relevant models were built using actual data from shippers based on a mileage system. At the same time, the suitability of each model, the availability of each factor and the relevant degree of influence were discussed in details.

The models constructed were used to conduct a detailed investigation into the influence of railway use on truckload freight rates. One result of the effectiveness of railway freight on logistics costs is that truck freight rates may fall by about 6% when shippers use railways for freight transport at the same time.

Although these models are insufficient to clarify every situation in the setting of freight rates, the results indicate that the method might be worthwhile as a new technique in the analysis of logistics costs, including truckload freight rates and shippers’ use of multiple modes of freight transport. Further studies are necessary in this area.

**References**


