Modeling Truck Route Choice Behavior by Traffic Electronic Application Data

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1. INTRODUCTION
Recent years, as use of maritime containers in international trade increased, volume of container trailers increased in road transport as well. To strengthen the nation’s international competitiveness, smoothing large truck (e.g. container trailer) movement is necessary. However, mechanism of truck transport has not been closely examined.
In Japan, large vehicles that exceed weight limit for roads such as international maritime container trailers are required to apply for a permit to road operators in order to drive on roads. This study simulated nationwide routes of international maritime container trailers to examine their actual situations, and analyzed the route choice mechanism quantitatively.

2. GENERATING INFORMATION OF TRUCK ROUTE CHOICE WITH TRAFFIC APPLICATION DATA
2.1 Overview of Traffic Application
Roads are built according to structural standards. The Government Order on Road Design Standards indicates maximum size and weight of vehicle on road (general limit) for the purpose of traffic safety. Road authorities specify the general limit for total weight at 25 tons and height at 4.1 meters at maximum on expressways or “weight designated road” which road authorities designate for safety of road structure and prevention of traffic hazard.
Vehicles that exceed general limits in length, height, or weight such as self-propelled construction machinery (e.g. truck crane), articulated trailer, maritime container trailers require applying for traffic permit. Non divisible cargos (e.g. construction machinery, large electric generator, train car, electric pole, etc.) require a permit as well. Number of applications for traffic permits has increased over the years.

2.2 Generating Information of Truck Route Choice using Traffic Electronic Application Data
The computerized Traffic Application system enabled applying for traffic permit either in CD-ROM or on the Internet. In the system, applicants must specify their route by selecting intersections using their “node numbers.” Originally, road network on this application system was based on a simplified version of FY2005 Digital Road Map (DRM), and data for new roads have been added afterward. More than one possible route can be selected in the application system, thus, data contain the routes never driven by those vehicles.

In this study, route information of traffic applications was matched to those on DRM with the following method. First, road network of the application system in 2005 was a simplified DRM, and data of “node number” on traffic applications were matched to the nodes on DRM directly. Next, routes were reproduced on DRM by searching intersections. Then, routes on DRM were matched to those on Road Traffic Census, so the routes can be analyzed with the Census queries such as road design standards (number of lanes, etc.), and congestion factor, as well.
3. TRAFFIC FLOW OF MARITIME CONTAINER TRAILERS

3.1 Distributions of Travel Distance and Road Type
Using data reproduced on road map, traffic conditions were identified such as distributions of travel distance and type of road used by maritime container trailers. About 30% of applications by those container trailers drive long-distance over 300km, and about 10% drive over 500km among those. Moreover, approximately 80% of container trailers drive on express highways and directly-controlled national highways.

3.2 Traffic Conditions in Tokyo City Center
Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) designated “International Freight Arterial Network” to smooth international freight. MLIT also implemented measures to remove traffic barriers (e.g. bridge, tunnel) on this network for container trailers which meet international standards (44 tons at full load and 4.1 meters in height at maximum). The network consists of mostly express highways and directly-controlled national highways, but no road in center of large-cities are included for preservation of living environment. However, according to the data generated in this study, it was clear that container trailers drive ordinary roads in Tokyo city center given that major ports are in the vicinity.

3.3 OD Distribution on a Particular Road
Here, we take National Route 4 as an example for its high traffic of maritime container trailers to analyze what types of container trailers take this road. Route data between origins and destinations are required in the traffic application system. Origins and destinations on Route 4 are calculated to examine how they are distributed. From Tokyo and Yokohama Ports, international maritime containers are delivered taking Route 4 through Tokyo city center. Their destinations are industrial complexes as far as in Northern Kanto Region and Tohoku Region.

4. DEVELOPING ROUTE CHOICE MODEL FOR INTERNATIONAL MARITIME CONTAINER TRAILERS

4.1 Model Overview
In general transport engineering, car traffic is assigned under assumption that a route with minimum generalized costs is selected, but, the generalized costs concern value of time (VOT) and monetary cost only. Large trucks such as international maritime container trailer have tendency to take into account of other factors at route choice such as “driving comfort” of road design as well as VOT and monetary costs. Moreover, VOT for maritime container trailers may differ from that of other freight trucks. Thus, this study examines multiple-route assignment model which maximizes
overlap ratio of estimated and actual routes using route choice factors for large trucks. For instance, the model estimates reduced parameters of generalized costs (extended generalized costs) with possible route choice factors such as road design standards (e.g. number of lanes), road designation (e.g. weight, height). Then, route choice characteristics for large truck, etc. were quantified for the purpose of network evaluation.

This study established route choice model for maritime container trailers using traffic flow of those container trailers generated with traffic application data.

4.2 Maximum Overlapping Model

Maximum Overlapping Model (Hyodo et al. (2000) or Hyodo et al. (2007)) estimates parameters that minimize extended generalized costs and maximize overlap between estimated and actual routes. The model includes extended generalized costs (composite variable of time and cost) as a link function and these costs decline due to road structural factors. Subsequently, it assigns all ODs with the AON(All or Nothing) technique.

Extended generalized costs, \( C^{rs}_{k} \), are expressed as follows:

\[
C^{rs}_{k} = \sum_{a \in L^s_k} C_a
\]

Where

- \( C_a \): Extended generalized costs of link \( a \)
- \( L^s_k \): Set of links included in the \( k^{th} \) route between zones \( r \) and \( s \)

\[
C_a = (t_a + f_a/w) \times \beta^d_1 \times \beta^{d_2} \times \cdots
\]

\[
= (t_a + f_a/w) \prod_{i} \beta^d_i
\]

\( t_a \): Travel time of link \( a \), \( f_a \): Toll of link \( a \) (for toll roads)
\( w \): VOT (yen/minute), estimated as a parameter
\( d_i \): \( i^{th} \) dummy variable that affects traffic of link \( a \) (road structure, etc.)

For example, dummy variable of weight-designated road

\[
d_i = \begin{cases} 
1 : \text{weight-designated road} \\
0 : \text{otherwise} 
\end{cases}
\]

\( \beta_i \): Parameter to be estimated (for the above weight-designated road, \( \beta_i < 1 \))

This model is called “Maximum Overlapping Model” because it calculates the maximum overlapping rate (in distance) with actual routes to estimate parameters \( w \) and \( \beta \).

Here, focus is to estimate parameters \( w \) for VOT, a factor of extended generalized costs of link \( a \), and \( \beta_i \) (i=1, 2, …) for dummy variables, a route choice factor (or vector \( \beta \)).

If more than one route were given in data and parameter estimate is perfect, estimated and actual routes will coincide based on this model structure. To obtain model parameters, they should be set to maximize overlap ratio. Here, it is defined mathematically for sample \( n \):

\[
D_s(w, \beta) = \frac{\sum_a \delta^{rs}_{na} \delta^*_{na}(w, \beta) \cdot l_a}{X_n}
\]

For the entire sample,

\[
D(w, \beta) = \frac{\sum_a \sum_n \delta^{rs}_{na} \delta^*_{na}(w, \beta) \cdot l_a}{\sum_n X_n}
\]
Where

\( D (w, \beta) \): Overlap ratio between actual and estimated routes
\( X_n : \): Actual route distance for sample \( n \), \( l_a : \): Distance of link \( a \)
\( \delta_{na} : =1 \) if actual route of sample \( n \) passes link \( a \), 0 = otherwise
\( \delta^*_{na} : =1 \) if estimated route of sample \( n \) passes link \( a \), 0 = otherwise
\( l_a : \): Distance of link \( a \)

With the above model, parameters \( w, \beta \), need to be specified to maximize the equation (3). Downhill Simplex Method was adopted to determine \( w \) and \( \beta \) systematically. This method estimates parameters \( w, \beta_i (i = 1, 2, \ldots) \) using the AON approach, then, determine \( \theta \) and \( \gamma \) to maximize the overlap ratio in (3).

### 4.3 Parameter Estimation of Maximum Overlapping Model

Parameter estimates of maximum overlapping models with sample of high-cube containers and all containers are presented in the Table 1 below. As parameters of dummy variable approach to zero, extended generalized costs decline, indicating explanatory variables have significant influence. In contrast, if parameters are over 1 it conflicts with the logic, and the model will not be adopted. If parameter equals 1, it indicates that this variable does not affect the model at all.

Estimate results for dummy variables such as multiple lane (dual two or more lanes) dummy, weight- and height-designated dummies, are generally between 0.4 and 0.6, indicating they affect on route choice.

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Model 1 (High cube containers)</th>
<th>Model 2 (All maritime containers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of time (yen/min.)</td>
<td>67.68</td>
<td>115.39</td>
</tr>
<tr>
<td>Multiple lanes (dummy) (dual 2 or more lanes)</td>
<td>0.4445</td>
<td>0.4954</td>
</tr>
<tr>
<td>Weight designated road (dummy)</td>
<td>0.3671</td>
<td>0.4198</td>
</tr>
<tr>
<td>Height designated road (dummy)</td>
<td>0.6106</td>
<td>0.6399</td>
</tr>
<tr>
<td>Overlapping ratio (%)</td>
<td>36.3</td>
<td>33.3</td>
</tr>
<tr>
<td>Number of samples</td>
<td>5,820</td>
<td>24,497</td>
</tr>
</tbody>
</table>

### 5. POLICY SIMULATION WITH DATA OF MARITIME CONTAINER TRAILERS

#### 5.1 Simulation Case

We estimated change in traffic flow using route choice model for maritime container trailers established in this study, assuming that roads are to be developed in the future.

In Tokyo Region, “International freight arterial network” has been designated to support maritime container flows, but not in city center for preserving living-environment. However, in reality, such container trailers enter the city center. This occurs because there are missing links in high-standard ring roads in Tokyo Region. Therefore, this study conducted simulation, assuming these three ring roads would be completed.

#### 5.2 Simulation Results

Completion of ring roads will result in increased maritime container traffic in existing express
highways. Moreover, such traffic will be decreased significantly in Tokyo city center. The results show that development of ring roads in Tokyo Region not only redirect traffic flow to roads in higher standards, but also improve environment in Tokyo city center.

<table>
<thead>
<tr>
<th>CO₂ emission in 5 prefectures* (t- CO₂/year)</th>
<th>With 3 ring roads</th>
<th>Without 3 ring roads</th>
<th>Change (with-without)</th>
</tr>
</thead>
<tbody>
<tr>
<td>98,161</td>
<td>100,774</td>
<td>-2,613</td>
<td></td>
</tr>
</tbody>
</table>

*Estimated for the link in 5 prefectures, Ibaraki, Saitama, Chiba, Tokyo, and Kanagawa.

5. Conclusion
This study generated route information of maritime container trailers using electronic data of traffic applications to develop a series of analytical technique for freight network evaluation, then, focused on analysis of International freight arterial network.
Since network for large trucks significantly affects freight efficiency and urban environment, it was analyzed as a part of the Tokyo Metropolitan Freight Survey as well, but, its sample was several hundreds. With a sample of hundred thousands of traffic applications, collecting nationwide route data was possible.
Such large sample allows more detailed examination of current traffic situations as well as possible contribution to improved analytical technique through various comparisons and model analysis.

REFERENCES

Tokyo Metropolitan Region Transport Planning Council (May, 2001) Vision for Integrated Transport System in Freight Perspective in Tokyo Metropolitan Region. (in Japanese)