An analysis of Truck Route Choice Behavior Based on the 5th Tokyo Metropolitan Freight Survey Data

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Abstract: Lately, private firms are in need of efficient transport using large trucks in order to increase efficiency of freight transport. Consequently, smoothing the traffic flow of large trucks is fundamental in terms of urban transportation. However, it is challenging to analyze the situations of large truck traffic with existing statistics. By analyzing freight vehicle probe data, we found that efficient freight traffic in Tokyo Metropolitan Area (TMA) has been hindered by missing links of ring roads and chronic congestion, and that urban environment may have been deteriorated due to large truck inflow in residential areas. In addition, analysis with truck route choice model revealed that there will be certain degree of effects in streamlining freight traffic and improving urban environment through future ring road development and extension of freight network.

Keywords: Freight Transport, Track Route Choice Behavior, Tokyo Metropolitan Freight Survey Data, Probe Data, Route Choice Model.

1. INTRODUCTION

In Japan, there is an increasing demand for the use of large trucks, including vehicles for international maritime containers, in response to the internationalization of logistics due to the deepening of the global supply chain and the need for efficient transport based on the strengthening of competitiveness and the overall lack of truck drivers. The shortage of truck drivers in recent years is associated with an actual labor shortage in long-haul trucks attributable to the severe work environment for drivers who must respond to specific arrival times and small lots and frequent transport, in addition to demographic structure changes from a declining and aging population with a low birth rate. To cope with the shortage of drivers, some corporations have introduced multi-modal or joint distribution system while some try to use large vehicles, Therefore, the facilitation of large truck traffic is critically important for logistics industry in Japan.

For this purpose, the Ministry of Land, Infrastructure, Transport and Tourism is building a highway network suitable for large truck traffic. In the Tokyo metropolitan area (TMA), the construction of a network of three-ring expressways is expected to be done by 2017. In addition, by specifying a high standard road network, wherein construction is even now advancing, as a zone for guiding large trucks to appropriately high standard roads, as well as alleviating traffic congestions in that special zone for guiding large trucks, the government has been building a road network to seamlessly link the logistic facilities.

As just described, the government is implementing measures to facilitate the use in Japan amidst the increasing need to use large trucks. However, it is difficult to sufficiently

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analyze the routes being used by large truck traffic from the existing statistics. Although previous studies analyzed the actual status and challenges of large truck traffic, few conducted an empirical analysis of the challenges faced by cities based on exhaustive data. This research conducts a preminaly analysis of the probe data, formulates a model, and simulates a policy with the goal of revealing the facts about large truck traffic in the TMA in order to satisfy both the need to increase the efficiency of freight transport and improve the urban environment in the TMA.

This study reviewed the existing research on truck route choice behavior and route choice models (2. LITERATURE REVIEW). In addition, we gathered and organized truck route data based on the fifth Tokyo Metropolitan Freight Survey (3. DATA COLLECTION). Next, based on the organized truck route data, our goal was to understand the movement of large trucks in the TMA, analyze the status of construction of the express highways, determine the truck traffic in residential areas, and analyze the actual traffic flow on the roads from different perspectives to clarify the challenges of facilitating truck traffic (4. PRELIMINARY ANALYSIS). Additionally, by constructing a truck route choice model based on the maximum overlapping model, we analyzed the characteristics of large truck route choices quantitatively and then estimated how the construction of ring roads in the future and the expansion of logistics networks would affect the efficiency of logistics and improve the urban environment in the TMA (5. MODEL FORMULATION and 6. POLICY SIMULATION). Last, we concluded by proposing logistics policies in the TMA from the viewpoint of urban transportation. (7. CONCLUSION)

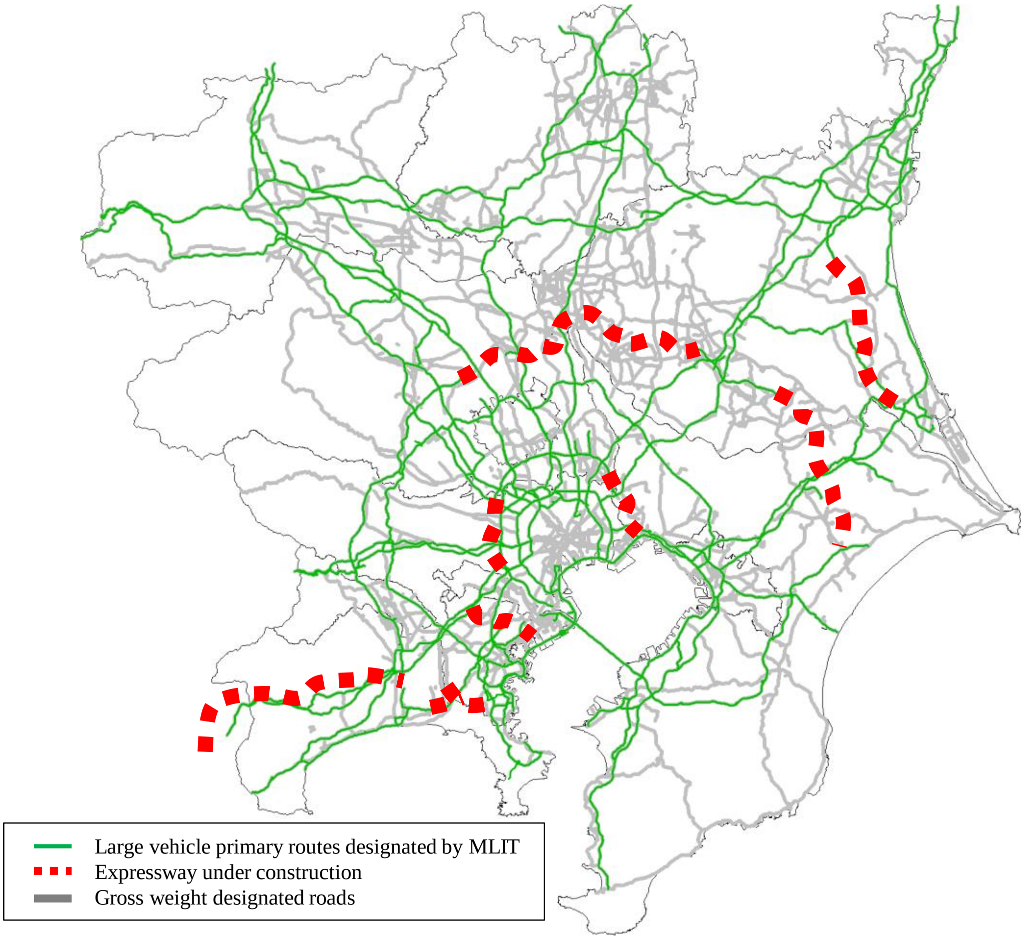

Figure 1. Current and future road network in TMA

2. LITERATURE REVIEW

2.1 Truck Route Choice Behavior

In japan, there have been a number of studies on route choices of large trucks from the viewpoint of expressway tolling and traffic congestion for smoothing the traffic flow of vehicles with international maritime containers.

N. Akita, et al. (2003) summarized the challenges for expressway tolling policy and analyzed the impact of tolling on the route choice behavior of vehicles carrying international maritime containers. Specifically, a survey was implemented to measure the intention of 269 offices based in Port Kobe and Osaka using questionnaires and revealed preference data. It revealed the intention of route switching in response to a change in toll. N. Akita, et al. (2005) also used revealed preference data of vehicles with international maritime containers arriving and departing from Port Kobe and Osaka to reveal the characteristics of short-distance trips and mid- to long-haul trips with the aim of predicting the changes in traffic routes when expressway tolls changed.

On the other hand, R. Shibasaki, et al. (2005a) organized the system for the actual status of traffic congestion and calculate the monetary value of time loss from bottleneck locations. In addition, taking into account the differences in loaded/empty transports, imports/exports, and destinations (sea route) for three types of international maritime containers—normal maritime containers, fully loaded maritime containers, and high-cube maritime containers, R. Shibasaki, et al. (2005b) implemented a stochastic network assignment calibrated from field data to infer the route choices of vehicles with international maritime container. The study further forecasted the effect of removing bottlenecks through the estimation of generalized cost of the traffic route of transport vehicles for international maritime containers.

2.2 Route Choice Model

Route overlapping and choice set generation are two important problems to be considered for route choice modeling. The first problem is, when two route alternatives contain overlap part on the road network, IIA (Independence from Irrelevant Alternatives) assumption is violated. This problem can be resolved by introducing some correlation structure to the utility function, such as the Path Size correction method (please cite some reference). The second problem is that the number of choices (paths) is virtually enormous on actual road networks, making it difficult to generate a feasible choice set. This can be settled by applying a method without enumerating the choice set, such as the Dial algorithm. Comprehensive reviews on route choice model can be found in J. N. Prashker and S. B. Carlo (2004), Giacomo Prato (2009), and T. Yamamoto (2012).

Many variants of route choice model has emgerged according to the ways of dealing with these challenges, meanwhile there are some new models that do not require choice set to be specified. T. Hyodo, et al. (2006) presented an maximum overlapping model as a methodology for modeling the route choice behavior of large trucks. T. Hyodo, et al. (2009) also suggested the Path Size Dial Logit model in consideration of the issue of overlapping routes and choice set generation, which has been traditionally identified in the route choice model. They then used a real-network application for model comparison with the aim of discovering more information about the issue of overlapping routes in the Dial algorism that was not overcome traditionally.

E. Frejinger et al. (2009) proposed a method based on choice sampling as a stochastic choice set generating method and validate it with the virtual network. After embedding the suggested method into the Path-Size logit model and applying it to the virtual network, a higher degree of conformance and repeatability of the current situation was confirmed relative to the normal Path-Size logit model. A. Papola and V. Marzano (2013) also suggested a new route choice model that applies the Network-GEV model and a traffic assignment algorithm that did not require enumerating explicit routes with the idea of describing the route overlap structure with highly theoretical and flexible closed-form (structure not including integration) type of discrete choice model. Additionally, M. Fosgerau et al. (2013) suggested the Recursive Logit Model that did not restrict (the necessity of listing routes) the choice set as a model for the link-based recursive route choice model. As a result of comparing the existing model and the Recursive Logit Model, the advantage of not requiring route enumeration was revealed while the estimation accuracy of the Recursive Logit Model was equivalent to MNL. Also, by introducing the Link Size term based on a similar idea with the Path Size Logit Model to the Recursive Logit Model, the overlap of routes was considered, which leads to higher estimation accuracy. To conclude, the Recursive Logit Model with the Link Size term suggests that it is possible to construct a model that can consider the overlap of routes without the need for listing routes.

On the other hand, while the construction of these models requires accurate route choice data by link unit, M. Bierlaire and E. Frejinger (2008) proposed a framework for reducing the errors from map matching when modeling the route choice behavior by handling ambiguous data obtained from a traffic route survey as is. By applying the suggested framework to the questionnaire survey results from Switzerland, the estimated results were compared after constructing the Path Size Logit Model and Subnetwork Model, respectively. As a result of the analysis, the estimated results obtained from two models indicated similar trends. While stable results were obtained even with a different model structure, the final likelihood of the Subnetwork Model was higher than the Path Size Logit Model, showing that the Subnetwork Model was likely to result in a better fit to reality

3. DATA COLLECTION

3.1 General Description of the 5th Tokyo Metropolitan Freight Survey

This research utilizes the data collected at the fifth Tokyo Metropolitan Freight Survey (Tokyo Metropolitan Traffic Planning Counsil). The Freight Survey focuses on products as the subject of traffic to mainly grasp the movement of trucks, as well as the products loaded on these trucks. In the TMA, the survey was conducted in 1972, 1982, 1994, 2003, and 2013.

The following shows the survey scheme and survey target areas of the fifth Tokyo Metropolitan Freight Survey implemented in 2013. The fifth Tokyo Metropolitan Freight Survey consists of questions to establishment as the main part of survey and multiple sub part of surveys including questions to company, interview survey, large truck route survey, and local delivery survey in CBD.

This research organizes the truck route data based on the probe data collected in the large truck route survey. In addition, the fifth Tokyo Metropolitan Freight Survey used a partially updated survey to understand the recent trend in logistics. The survey also adopted an efficient method based on the advancement of survey technology in recent years, such as the utilization of probe data, for understanding the traffic routes of trucks.

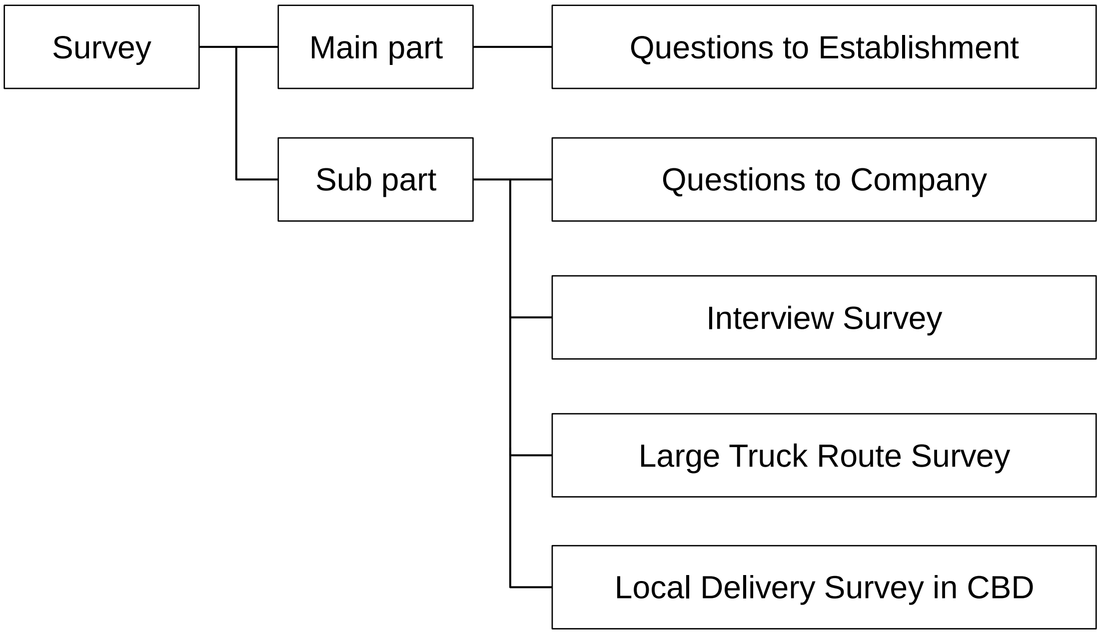

Figure 2. Fifth TMA freight survey scheme

□: New areas added for this survey

Figure 3. Fifth TMA freight survey areas (colored areas)

3.2 General Description of the Probe Data

In recent years, the accuracy of GPS devices improved significantly, allowing for easy understanding of the trajectories of vehicles. There are many cases in which logistics companies install digital tachographs on their vehicles to record the real-time trajectory by using GPS for operations and safety management. In light of this, the fifth Tokyo Metropolitan Freight Survey used different types of probe data, including digital tachographs owned by operators, to conduct a lager truck route data. The probe data collected by different methods are shown below in details.

The data from the collection method 1 is the truck travel path within the TMA, which was obtained from the digital tachograph data collected by an on-board equipment maker. While the data 1 tended to have more spatial completeness, its temporal resolution was lower because the location information is updated every ten minutes.

The data of collection method 2 was the truck trajectory entering and exiting from several logistic facilities within the TMA, which was obtained from the digital tachograph data collected by trucking companies. While the data 2 tended to have less spatial completeness, its temporal resolution tended to be higher because the acquisition interval was from one second to 60 seconds.

The data from the collection method 3 was the truck trajectory obtained by requesting individual logistic facilities to install a GPS device. The data 3 was from the GPS devices on 84 trucks with international maritime containers and 188 large trucks with the maximum load capacity of 10 tons, and the trajectories of approximately a week were measured for each truck. While the survey data had less spatial completeness, the data resolution tended to be higher because the acquisition interval of probe data was two seconds.

For the data of collection methods 1 and 2, the location information of trucks and the types of relevant truck were also surveyed. For the data of collection method 3, by conducting a questionnaire survey along with the installation of GPS device, the location information of trucks, container size, and main transportation items and the issues of traffic route were surveyed.

Based on the characteristics of each data set as described above, this research analyzed the movement of trucks from both macroscopic scope (i.e., inter-regional OD) by data 1 and 3and microscopic scope (i.e., truck inflow into residential areas) by data 3. The data 2 is not included in the analysis. The collected travel path data was used to analyze as line data by map-matching on a digital road map and as surface data by corresponding to a standard region mesh.

Table 1. Characteristics of three kinds probe data

Category	Collection method	Data interval	Area	Volume of data to collect	Vehicle category e.g. large truck, etc.
Method 1	Collection from OBU maker collectively	10 min	Vehicles pass through TMA	13,000 vehicles*day	Large truck, towing vehicle
Method 2	Collection from trucking companies	1-60 sec	Vehicles that belong to establishments in TMA	3,000 vehicles*day	Large truck, towing vehicle
Method 3	Install GPS in individual establishments	2 sec	Vehicles that belong to establishments in TMA	1,900 vehicles*day	Int. maritime container truck (40 ft high-cube, 40 ft, 20 ft), and other (max. load 10+ ton)

4. PRELIMINARY ANALYSIS

4.1 Recent Trend of Freight Transport in TMA

The mode shares of freight transport in the TMA show that more than 90% of the logistics of travel within the TMA and nearly 60% of the logistics of travel to and from outside and inside of the TMA were by trucks. This suggested that the impact of facilitating truck traffic was extremely high on increasing the efficiency of freight transport in the TMA. In addition, according to the composition ratio by load capacity of trucks traveling to and from logistics facilities in the TMA, the ratio of lager trucks with the maximum load capacity of 10 tons increased by 6 points from 19% to 25% in the last decade, indicating a growing need for large trucks in recent years.

Ideally, large trucks should travel on high-standard roads like expressways instead of residential or downtown areas. By looking at the use of expressways for large trucks based on the probe data (by method 3), many trucks use expressways when distances exceed 50 km in the TMA. For a distances below 50 km, many trucks use regular roads. While some corporations intend to use expressways to improve transport efficiency and shorten work hours, some are reluctant to pay the relatively high expressway tolls.

At present, the construction of ring expressways is underway in the TMA, and in 2017, three ring roads will be completed. In recent years, amidst the increasing need to use large trucks, it would be ideal to suppress the truck traffic flowing into residential and downtown areas by promoting the appropriate use of ring roads and expressways with the aim of satisfying both the efficiency of freight transport and improvement of the urban environment. The analysis below analyzed the movement of large trucks in the TMA from perspectives of both macroscopic broad-area flow and microscopic inflow in residential areas.

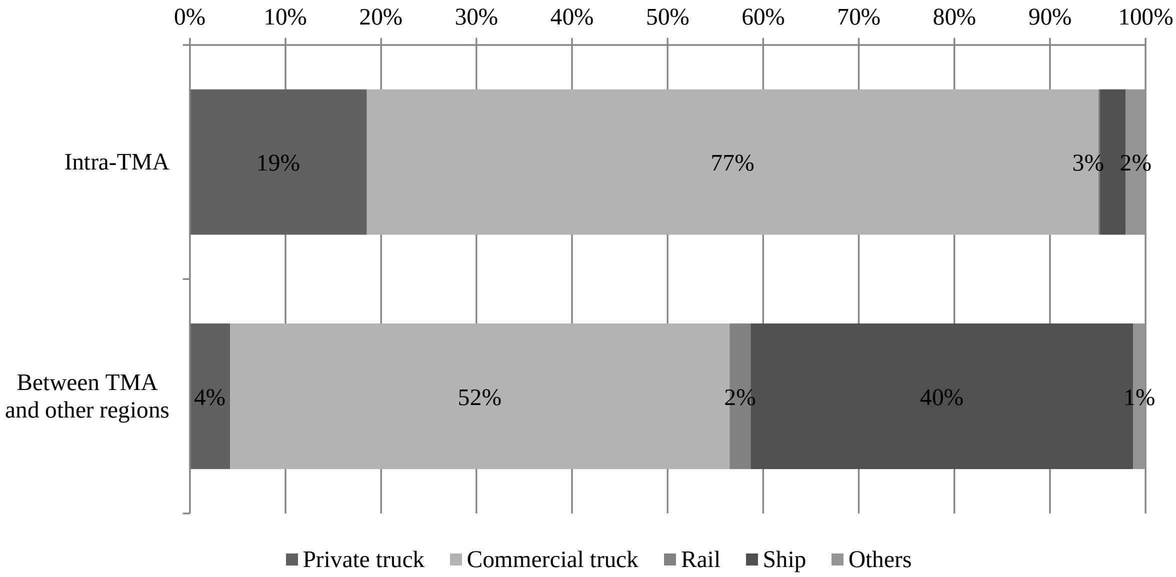

Figure 4. Commodity flow by modal share

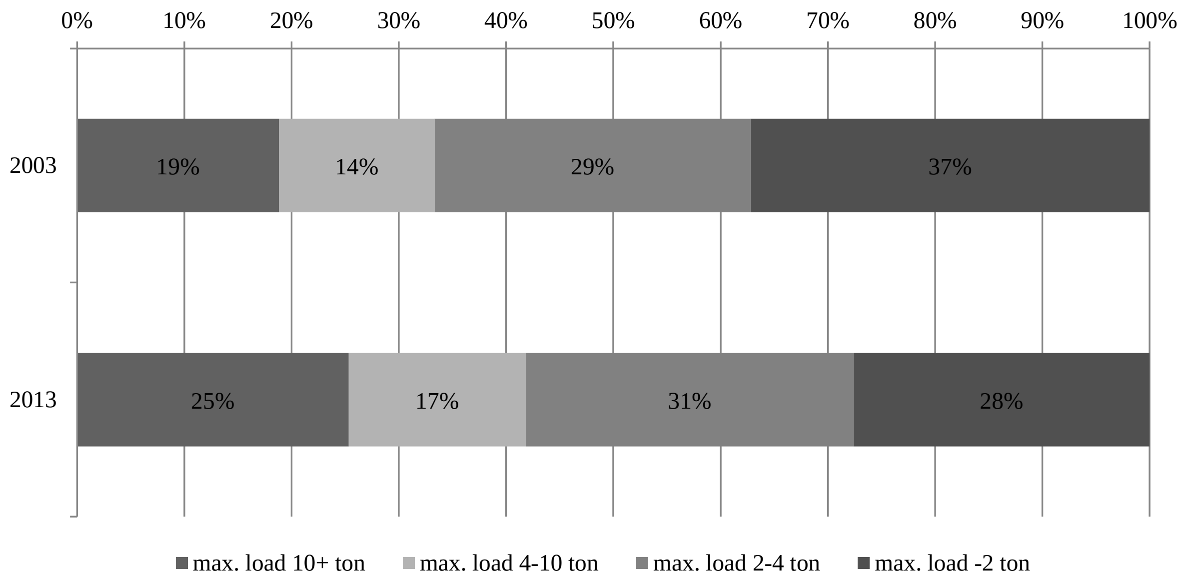

Figure 5. Commodity flow by maximum load capacity

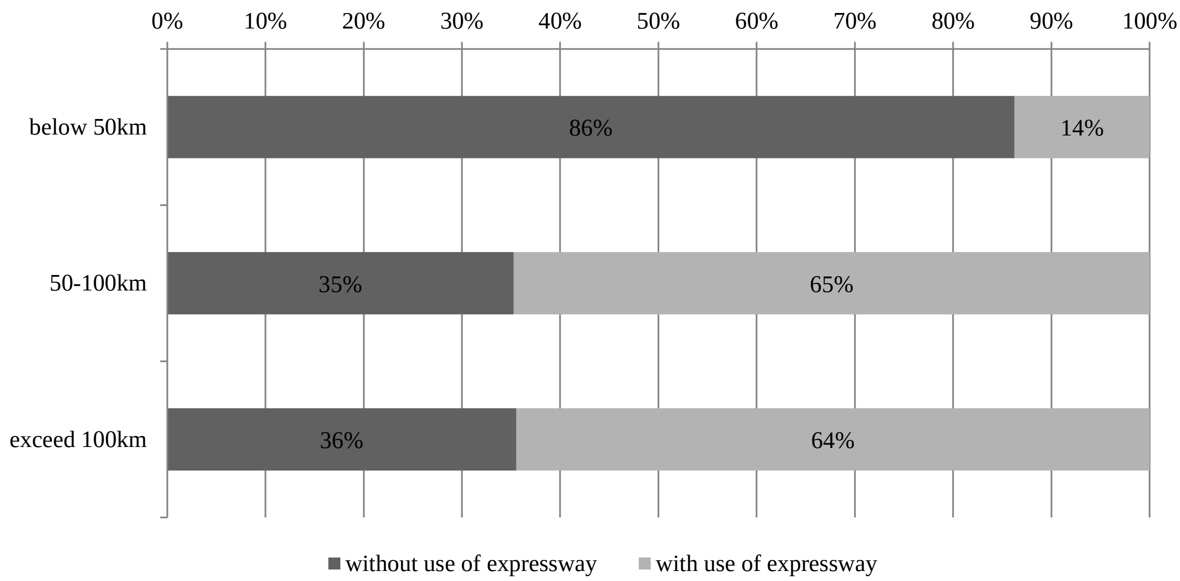

Figure 6. Use of expressways for large trucks

4.2 Macroscopic Truck Behavior in TMA

This section analyzes the macroscopic movement from the viewpoint of origin and destination and interregional OD flow of the trucks in the TMA.

By looking at the movement of trucks by the time of a day according to vehicle types by road type, large trucks tend to travel expressways at night, and vehicles carrying international maritime containers traveling on expressways tend to increase from the daytime to early evening, indicating different trends of trucks for the time of a day and vehicle types. In addition, vehicles carrying international maritime containers are likely to travel other roads in the early morning and the early evening. This is because vehicles carrying international maritime containers accumulate around the waterfront area during the relevant time of the day.

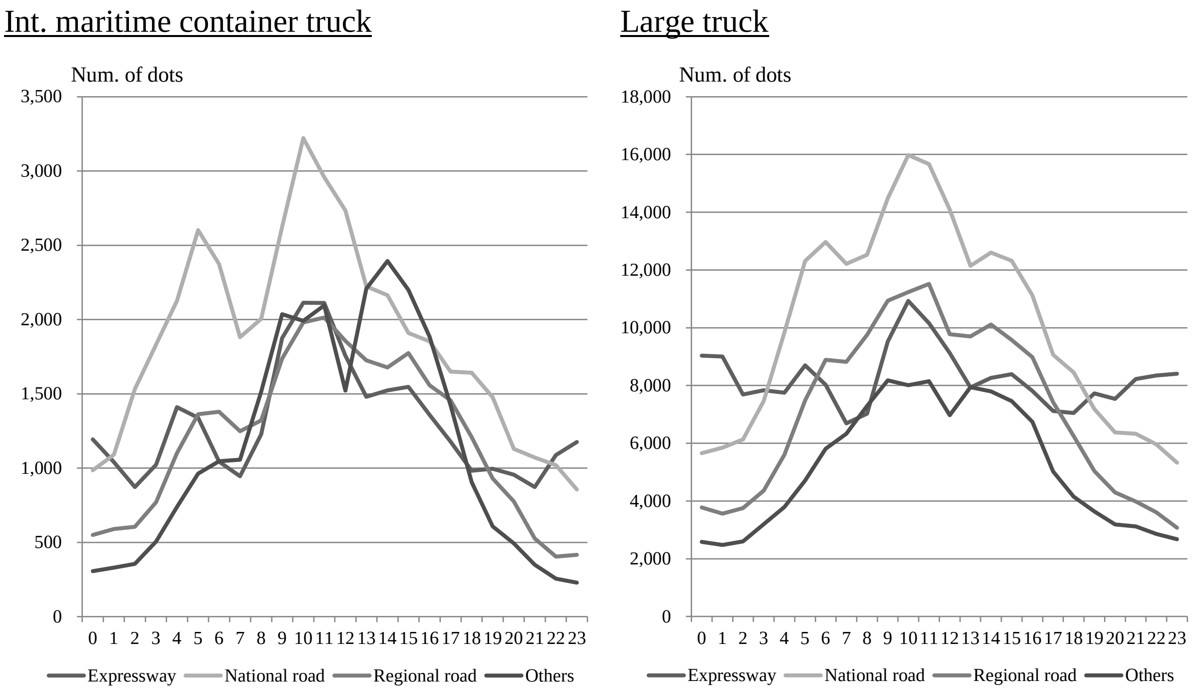

Figure 7. Number of dots by time slot and road kind

By looking at the arrival and departure locations of large trucks in the TMA, the arrival and departure locations of vehicles carrying international maritime containers are distributed along the ocean in Chiba, Tokyo, Kanagawa, and Ibaraki and inland areas in Tochigi and Gunma. On the other hand, the origin and destination of large trucks are distributed across the inland areas compared to vehicles carrying international maritime containers, particularly along the ring roads of the Metropolitan Inter-city Expressway in Saitama and Kanagawa and North Kanto Expressways, which are areas with heavy traffic.

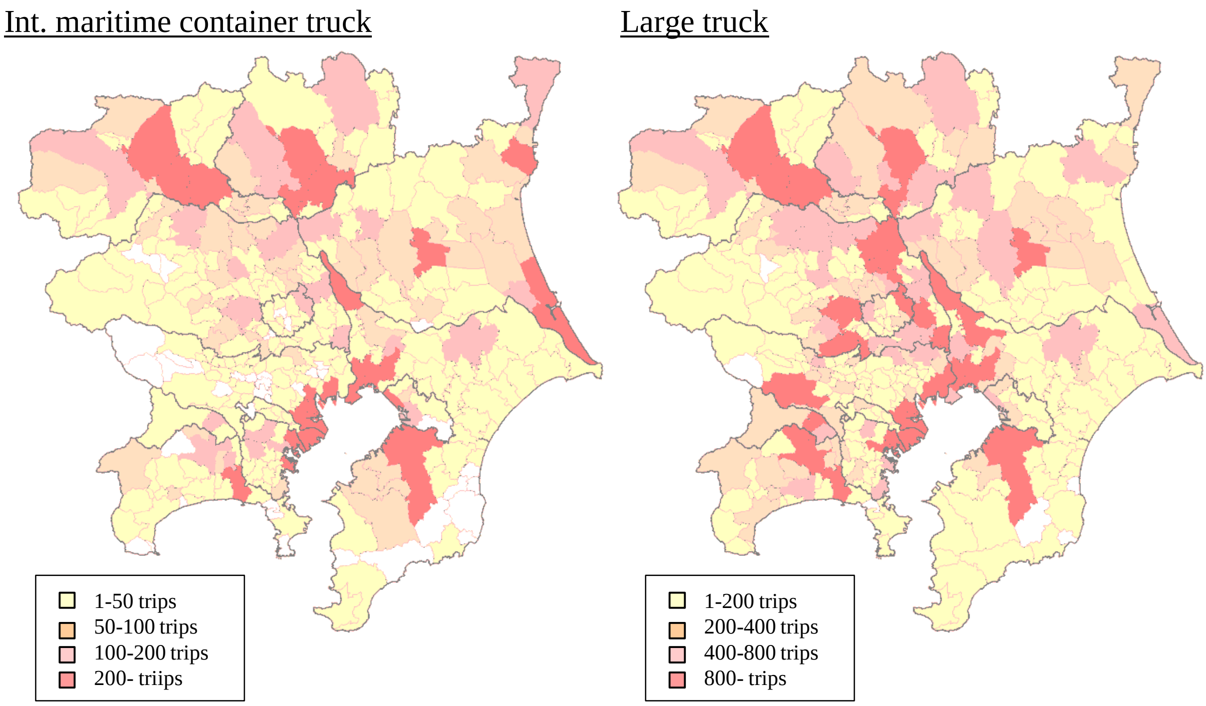

Figure 8. Volume of trip generation and attraction in each city/ward

By taking particular note of OD travel inter-regionally, several issues have been raised as to the traffic of large trucks, including the decline of transport efficiency caused by congestion due to lower traffic rates on expressways and the occurrence of truck inflow in residential areas, mainly in the areas where there is no sufficient logistic network to support large trucks and where the ring road projects are underway.

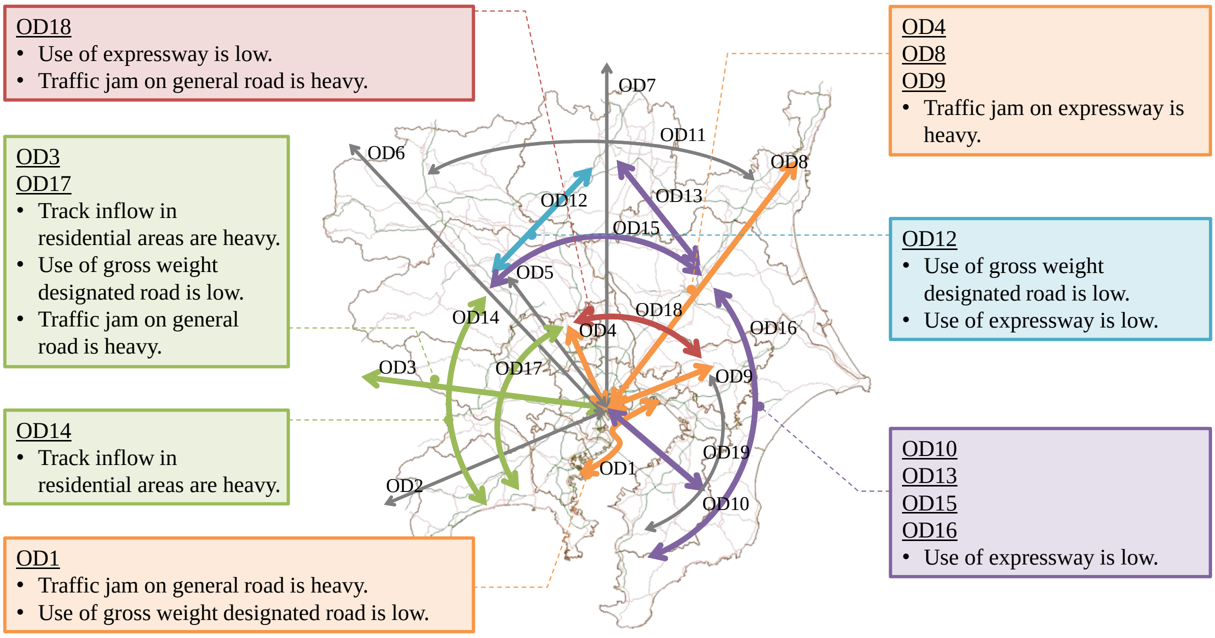

Figure 9. Summary of macroscopic issues from the viewpoint of truck behavior in TMA

Table 2. Macroscopic issues in each inter-regional OD in TMA

	Int. maritime container truck					Large truck				
	Use of express way	Use of gross weight designated road	Inflow into residential areas	Traffic jam on express way	Traffic jam on general road	Use of express way	Use of gross weight designated road	Inflow into residential areas	Traffic jam on express way	Traffic jam on general road
OD1	+6pt.	+0pt.	-1pt.	-2pt.	+0pt.	-1pt.	**-5pt.**	-1pt.	+0pt.	**+4pt.**
OD2	+15pt.	+16pt.	+2pt.	-6pt.	-3pt.	+12pt.	+7pt.	+0pt.	+0pt.	+1pt.
OD3	**-23pt.**	+12pt.	**+4pt.**	-3pt.	-6pt.	+3pt.	**-9pt.**	**+8pt.**	+0pt.	**+6pt.**
OD4	+14pt.	+0pt.	+1pt.	-1pt.	**+3pt.**	+8pt.	+0pt.	+0pt.	**+5pt.**	+2pt.
OD5	+21pt.	+13pt.	+0pt.	+0pt.	-3pt.	+15pt.	+6pt.	+0pt.	+1pt.	+1pt.
OD6	+0pt.	+11pt.	+0pt.	+2pt.	-6pt.	+26pt.	+8pt.	+0pt.	-2pt.	-2pt.
OD7	+33pt.	+18pt.	-1pt.	-4pt.	-6pt.	+11pt.	+9pt.	-1pt.	+2pt.	-2pt.
OD8	+23pt.	+18pt.	-1pt.	-2pt.	-4pt.	+21pt.	+6pt.	-1pt.	**+4pt.**	+0pt.
OD9	-1pt.	+13pt.	+1pt.	-2pt.	-3pt.	-1pt.	+6pt.	+0pt.	**+3pt.**	+1pt.
OD10	**-16pt.**	+10pt.	+1pt.	-5pt.	-2pt.	+18pt.	+4pt.	+0pt.	-3pt.	-1pt.
OD11	-	-	-	-	-	-2pt.	+4pt.	-1pt.	-3pt.	-4pt.
OD12	-	-	-	-	-	**-19pt.**	**-4pt.**	-1pt.	-3pt.	-3pt.
OD13	-	-	-	-	-	**-36pt.**	+2pt.	-2pt.	-2pt.	-6pt.
OD14	-	-	-	-	-	+1pt.	-1pt.	**+3pt.**	+0pt.	+2pt.
OD15	-	-	-	-	-	**-28pt.**	+0pt.	-1pt.	-4pt.	-3pt.
OD16	-	-	-	-	-	**-17pt.**	+1pt.	+0pt.	-4pt.	-3pt.
OD17	-	-	-	-	-	+2pt.	**-4pt.**	**+3pt.**	+0pt.	**+7pt.**
OD18	-	-	-	-	-	**-22pt.**	+3pt.	+1pt.	+2pt.	**+4pt.**
OD19	-	-	-	-	-	+3pt.	+2pt.	-1pt.	-4pt.	-3pt.

*value is difference with average share of TMA.

4.3 Microscopic Truck Behavior in TMA

This section analyzes the microscopic movement of trucks in the TMA from the viewpoint of inflow in residential areas.

The lager truck route data has revealed the actual condition of truck inflow in residential areas in the TMA as follows. Mainly in Tokyo and Kanagawa, the truck inflow in residential areas is distributed in parts of Saitama, Chiba, Ibaraki, and Gunma. While the inflow in residential areas is caused in a broad inner-city area, in which the demand for large truck traffic is high and regular roads are congested, the results indicated the possibility that the inflow in residential areas occurs even in other areas besides the inner-city area.

In addition, the inflow pattern of vehicle inflow in residential areas indicates that the inflow caused from through traffic and the inflow caused from a mixture of residential areas and logistic facilities occur at similar percentages in the TMA.

Additionally, by looking at individual causes of inflow with a focus on the residential areas, we confirmed the contributing factors of insufficient gross weight designated roads, inadequate alternative routes with missing road links, detour traffic with hard-to-turn intersections, and detours from congestion on arterial roads, indicating several factors for the inflow depending on the area. For instance, large trucks traveling between Port Keihin and the inland area drive through residential areas. Although the arterial roads of Fuchu Kaido and Kanpachi Dori run parallel to the relevant routes, both Fuchu Kaido and Kanpachi Dori are congested on a daily basis, and the travel time varies significantly, possibly causing the inflow in the relevant routes.

As described above, the analysis based on probe data clearly show the growing need for large trucks in the past decade, several issues relevant to facilitating freight transport across a broad area within the TMA and the potential traffic flowing into residential areas.

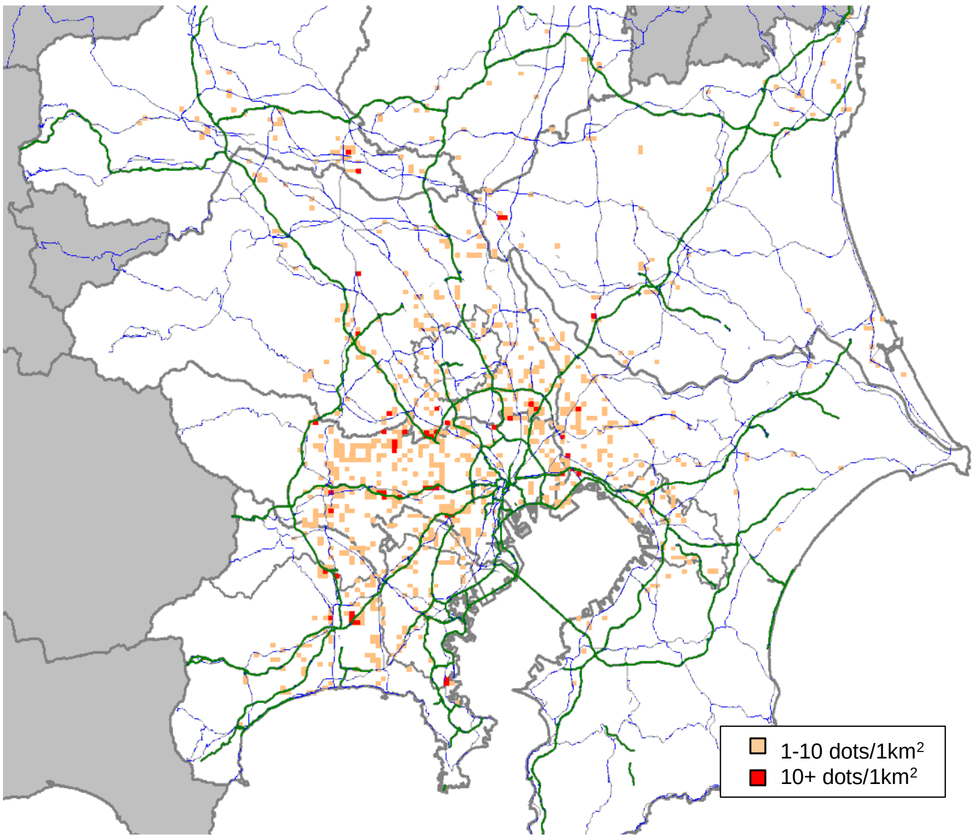

Figure 10. Actual condition of large truck inflow in residential areas

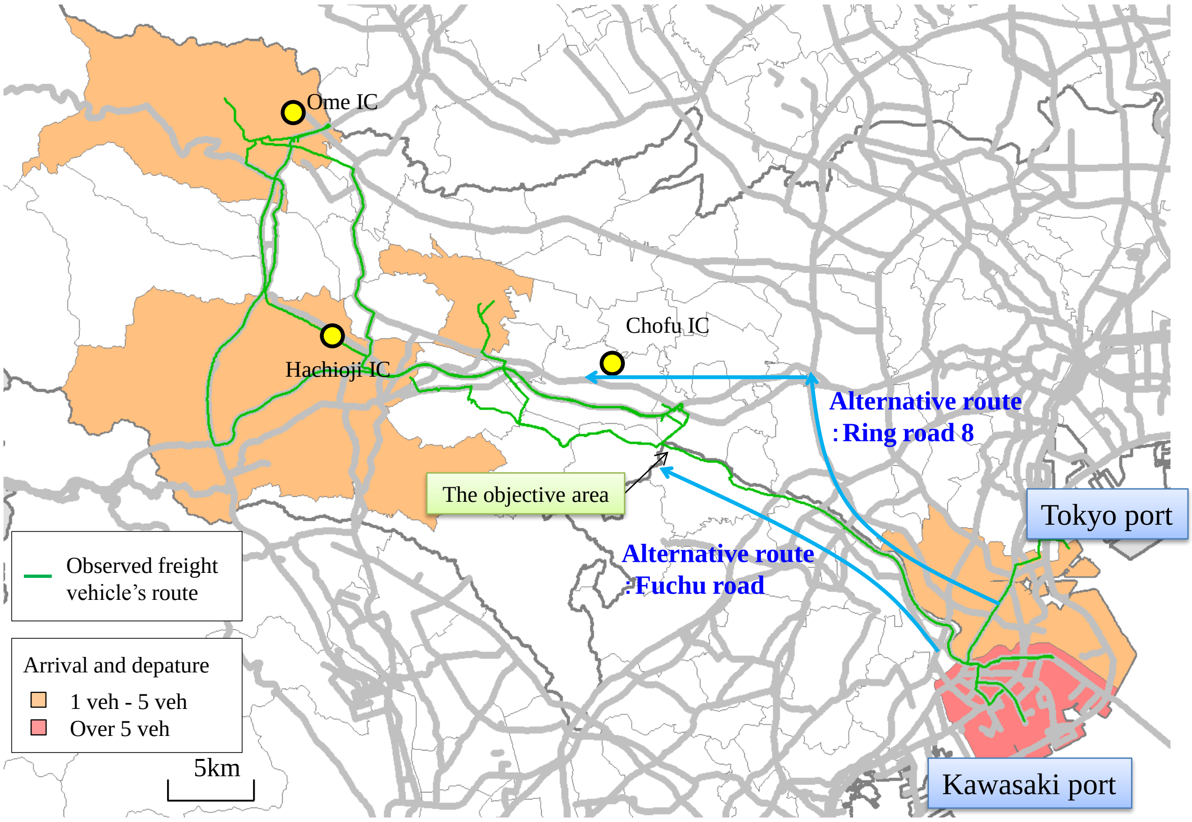

Figure 11. Individual causes of inflow with a focus on the residential areas

5. MODEL FORMULATION

5.1 Maximum Overlapping Model

This section uses the traffic route data of large trucks obtained from the lager truck route data to build a route choice model which represents the characteristics of large trucks. Large trucks prefer to travel on the roads suitable for large trucks, such as expressways and national highways, holding travel time and costs constant.

Based on the route choice behavior supposed for large trucks and assuming that the travel time and costs are perceived as relatively small (perceived generalized cost) on roads suitable for large trucks to travel, this research estimates the routes with the minimum perceived generalized cost. The perceived generalized cost is given by the following formula:

$$C_k^{rk} = \sum_{a \in L_k^{rk}} C_a \tag{1}$$

C_a: Expanded generalized costs of link a
L_k^{rk}: Set of links included in the kth route between zone r and s

$$C_a = (t_a + \frac{f_a}{w}) \prod_i \beta_i^{d_i} \tag{2}$$

t_a: Travel time of link a
f_a: Toll of link a (for toll roads)
w: Value of time (JPY per minute), estimated as a parameter
d_i: ith dummy variable of road type of link a
β_i: ith parameter to be estimated

The parameters w and β are estimated by maximizing the likelihood between actually chosen route and route with minimum estimated perceived generalized cost. This model is called the maximum overlapping model, meaning that when multiple actual routes are given, in the maximum overlapping model, estimated routes and actual routes match completely if perfect parameters are obtained. In order to obtain the model parameter, the parameters need to be determined so that this overlap rate is maximized.

Equation (3) is used to define the overlap rate for sample n. The estimation process is to find values for w (value of time, which is a component of perceived generalized cost of link a) and the road-type-specific constants βi such that the overlap rate is maximized. This research uses a downhill simplex method to search w and β systematically.

$$D_n(w,\beta) = \frac{\sum_a \delta_{na}\delta_{na}^*(w,\beta)l_a}{X_n} \quad (3)$$

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

5.2 Parameter Estimation Results

The estimation results in the maximum overlapping model are shown in the following table. The parameters for the perceived generalized cost are estimated to be 44.3 [yen/minute] for the time value, 5.43 for the non-weight-designated road dummy, 0.957 for the expressway dummy, 0.575 for the direct national route dummy, and 0.328 for the general road dummy. These results quantitatively indicate that large trucks tend to detour roads that are difficult to travel besides gross weight designated road and prefer to travel on expressways, direct national roads, and other specific general roads that are easy to travel.

Subsequently, the proposal route choice model is verified by comparing the actual traffic route obtained in the lager truck route data and the traffic route estimated in the model. For actual traffic routes, while the share of expressways is 37%, the share of regular roads is 34%, the share of other types of road is 29%; the traffic route estimated from the proposed model showed that the shares of expressways, regular roads and other types of road are 44%, 39% and 16% respectively. In addition, the overlap rate of estimated traffic route and the actual traffic route is 51%. This indicates that, in over half of road sections, the estimated travel route and actual travel route match completely. As a result, it proves a certain degree of description power of the proposed model, though it cannot perfectly reproduce the route choices on expressways and regular roads.

Table 3. Parameter estimation results

Explanatory variables	Coefficients
Value of time (yen/min.)	44.3
Non-weight designated road (dummy)	5.43
Expressway (dummy)	0.957
National road (dummy)	0.575
Specific general road (dummy)	0.328
Overlap ratio (%)	50.8%
Number of samples	544

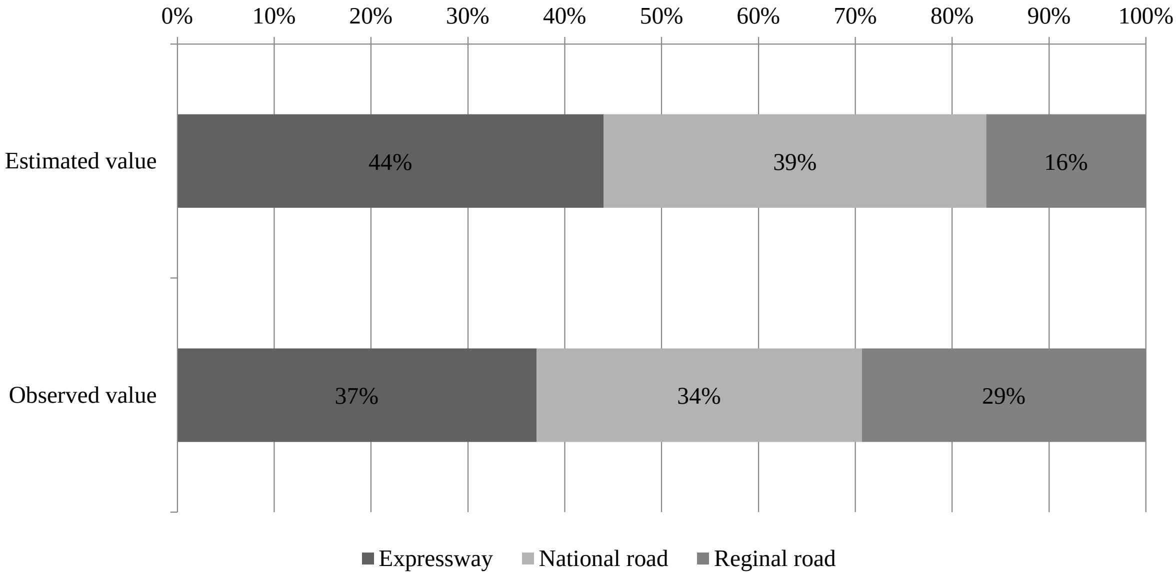

Figure 12. Share of observed and estimated value by road kinds

6. POLICY SIMULATION

6.1 Simulation Cases

Based on the route choice model constructed in this research, we estimated the degree of impact that road construction will have on the flow of large trucks. As described above, the construction of ring expressways is underway in the TMA, and in 2017, three ring roads are expected to be completed. In addition, from the viewpoint of constructing a road network suitable for large trucks, there is an expansion of gross weight designated roads on which vehicles with a total weight of 25 tons can travel freely. As the need of using large trucks has been increasing these years, it is sound to control the truck traffic in residential and downtown areas by promoting the proper use of ring roads and expressways, which can hopefully improve not only the efficiency of freight transport but also the urban environment.

Based on such circumstances, the simulation in this research was set as follows. From the viewpoints of the rationalization and streamlining of the traffic of large trucks and the inflow control, case one analyzed the impact of the construction of three ring roads on the flow of large trucks, and case two analyzed the impact of the expansion of gross weight designated roads on the flow of large trucks.

In the simulation based on the constructed model, the inter-regional OD flow of large trucks in the questions to establishment is assigned on the road networks using the all-or-nothing assignment approach to get the estimated traffic flow of large trucks by routes.

Table 3. Simulation cases

	Outline of simulation cases	
Case1	Construction of Three Ring Road	
Case2-1	Expansion of Gross Weight Designated Road	Making an improvement in all national roads
Case2-2		Making an improvement in all national roads and all major regional roads

6.2 Simulation Results

6.2.1 Case1: Construction of Three Ring Road

By focusing on the formation of core road networks by the construction of three ring roads in the future, we analyzed the effect quantitatively. As a result, large trucks traveling through the city center, including the metropolitan expressways and regular roads, would move to ring roads, such as the Metropolitan Inter-city Expressway and outer ring roads, reducing the traffic by large trucks on a part of regular roads and the inner-city area.

In addition, the construction of expressways in the future are expected to increase the share of expressway usage for large trucks, while reducing the total traffic (vehicle*hour) by 13 % in the entire TMA indicating a large improvement on the efficiency of freight transport.

Moreover, the model predicted that the traffic (vehicle*kilometer) on residential aras in the TMA will be down by about 16% and the CO2 emissions by about 6%. These results indicate that the construction of expressways not only improve the efficiency of freight transport within the TMA, but also possibly have a significant effect on improving the living environment.

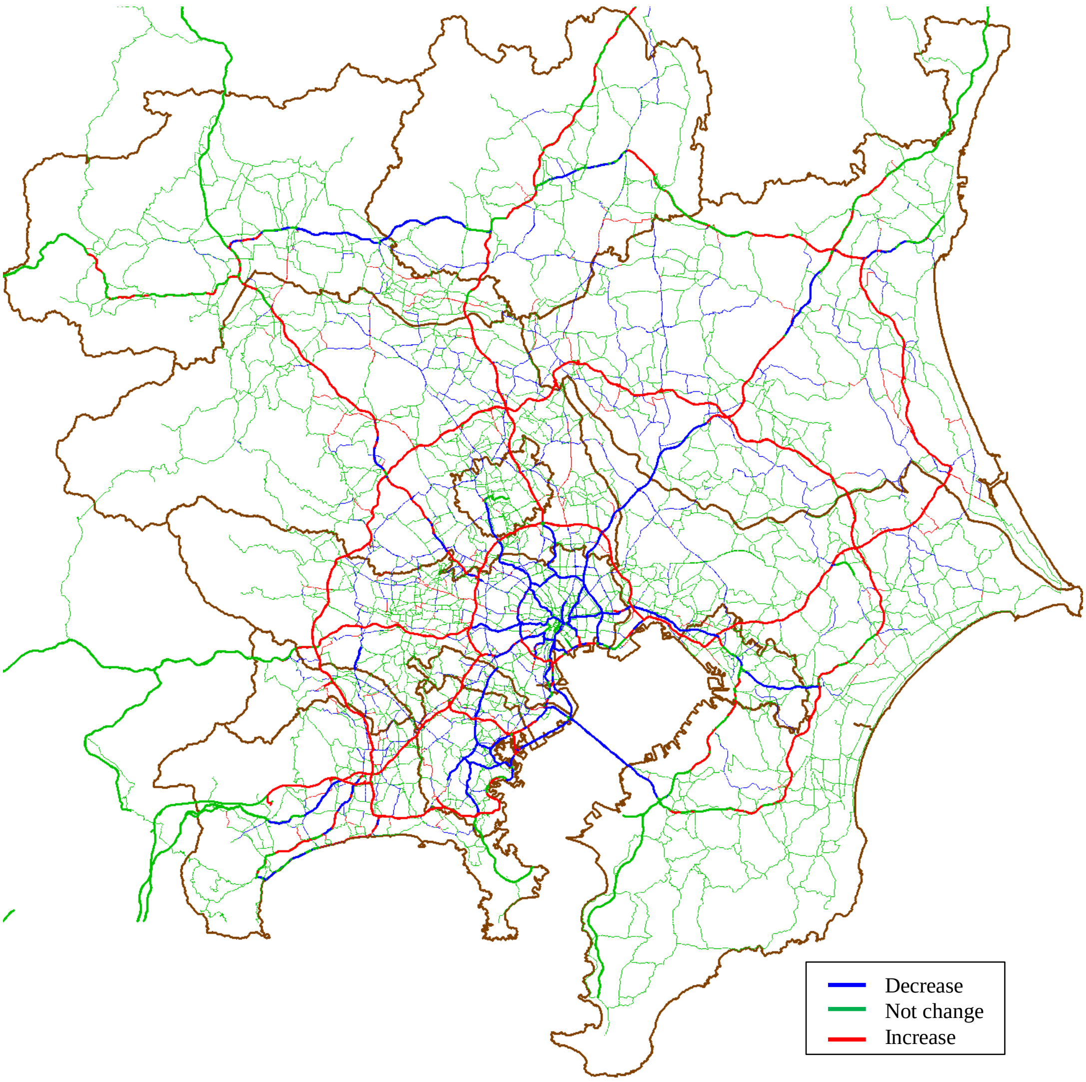

Figure 13. Change of traffic flow by construction of three ring roads

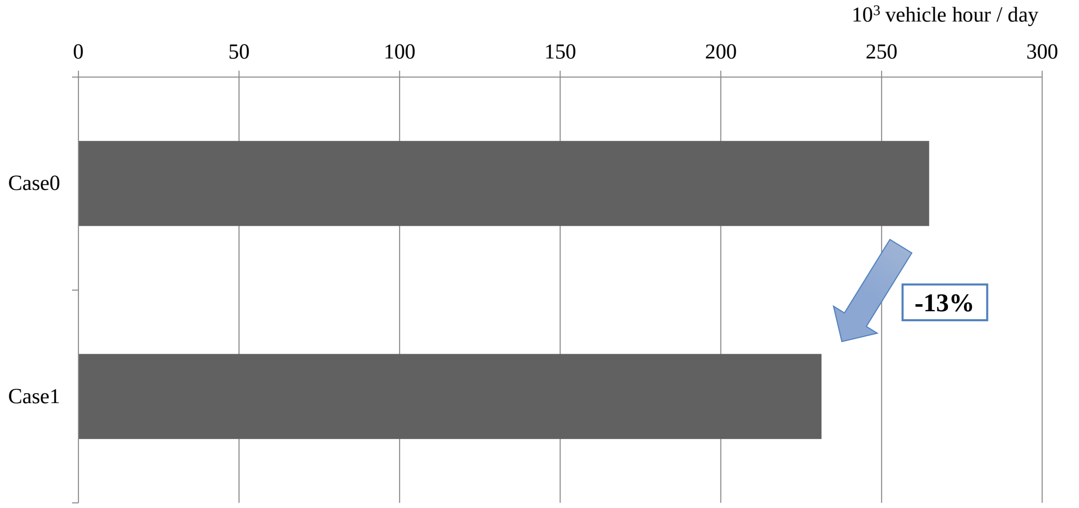

Figure 14. Change of total vehicle hour

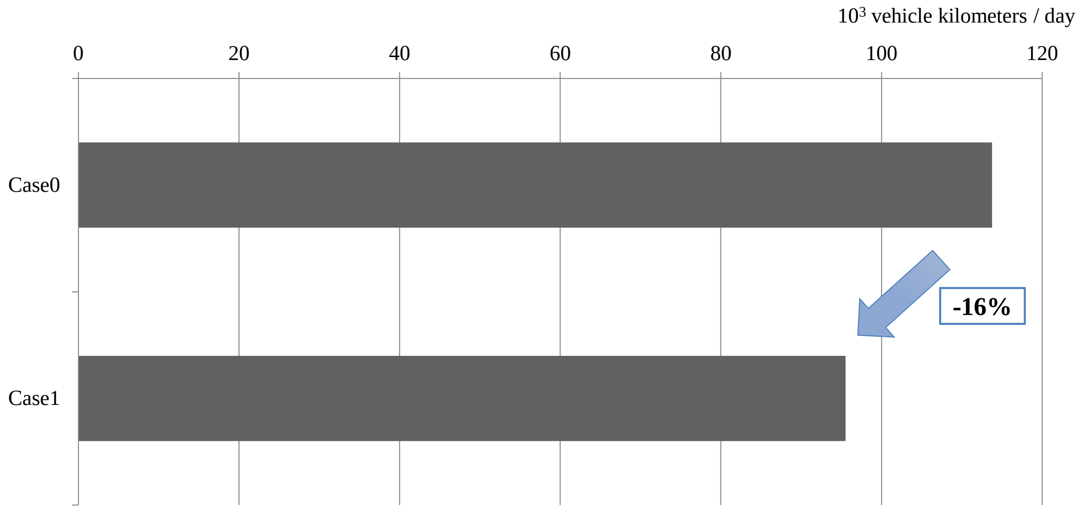

Figure 15. Change of vehicle kilometers in residential area

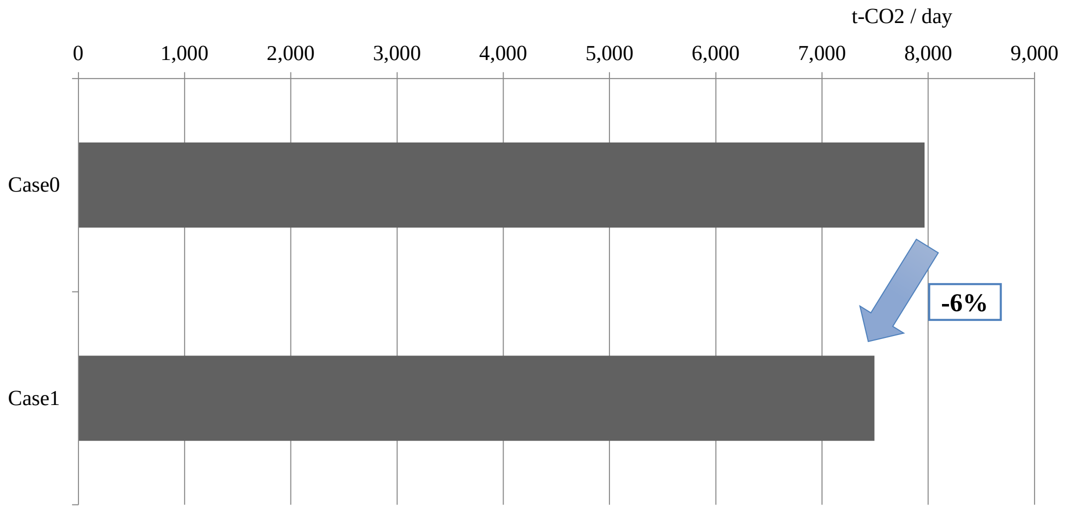

Figure 16. Change of total CO2 emissions

6.2.2 Case2: Expansion of Gross Weight Designated Road

As the measure to be implemented in the TMA, we focused on the formation of core road networks with the expansion of gross weight designated roads to analyze the effect quantitatively. The expansion of gross weight designated roads will shift the large trucks previously concentrated on expressways to arterial roads, such as national roads and major regional roads, reducing the total traffic (vehicle*hour) and thus more environment-friendly.

The expansion of gross weight designated roads will reduce the share of expressway usage for large trucks in the entire TMA. Meanwhile, the traffic (vehicle*hour) is predicted to decrease by nearly 1% in Case 2-1 and further down by nearly 4% in Case 2-2.

On the other hand, with the expansion of gross weight designated roads, the traffic (vehicle*kilometer) on local roads in the TMA are estimated to decline by nearly 1% in Case 2-1 but increase by nearly 19% in Case 2-2.

The analysis shows that, although constructing roads suitable for large trucks (e.g., gross weight designated road) can improve the efficiency of freight transport within the TMA, it entails a risk of deteriorating the living environment in urban residential areas by spreading the freight traffic into local roads. In other words, it is necessary to guide large trucks to high standard roads and rationalize and promote the construction of roads suitable for large trucks in order to satisfy both the efficiency of freight transport and improvement of the urban environment in the TMA.

Case2-1 Case2-2

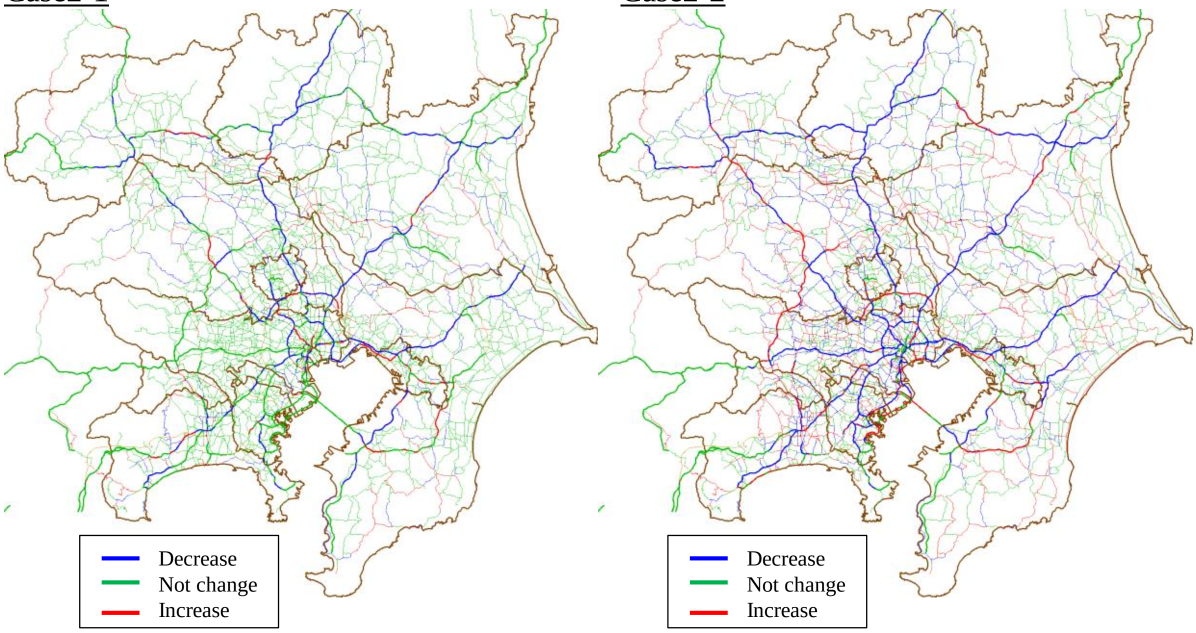

Figure 17. Change of traffic flow by expansion of gross weight designated road

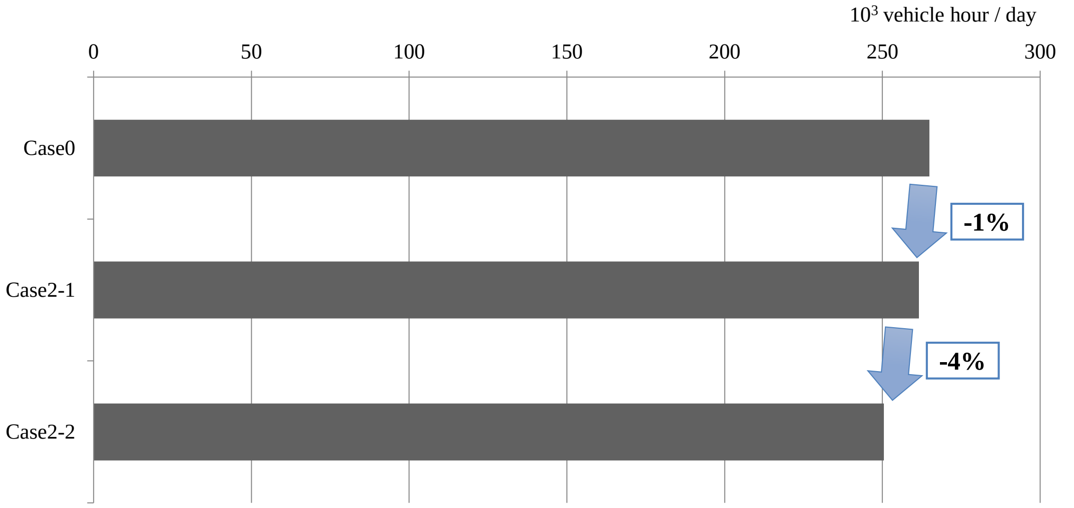

Figure 18. Change of total vehicle hour

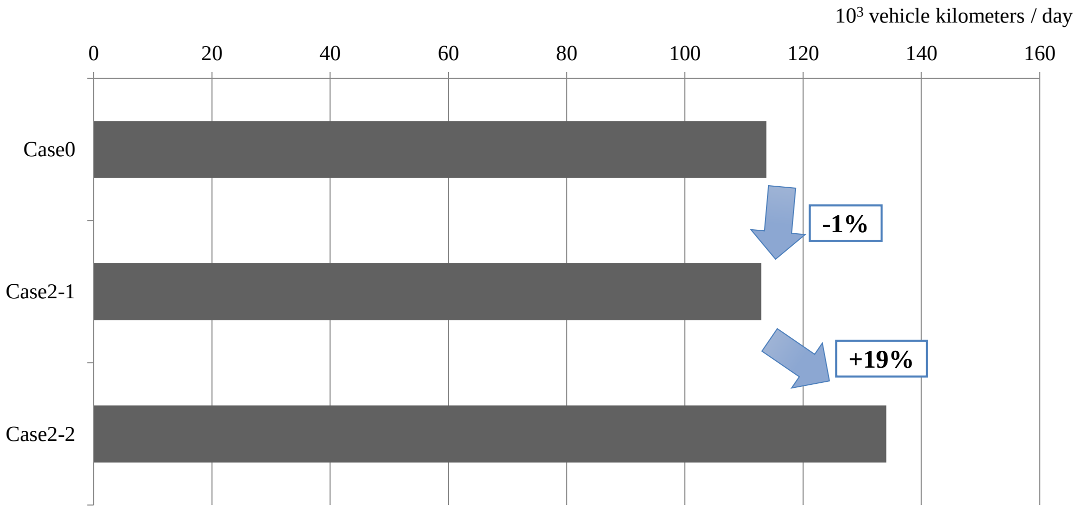

Figure 19. Change of vehicle kilometers in residential area

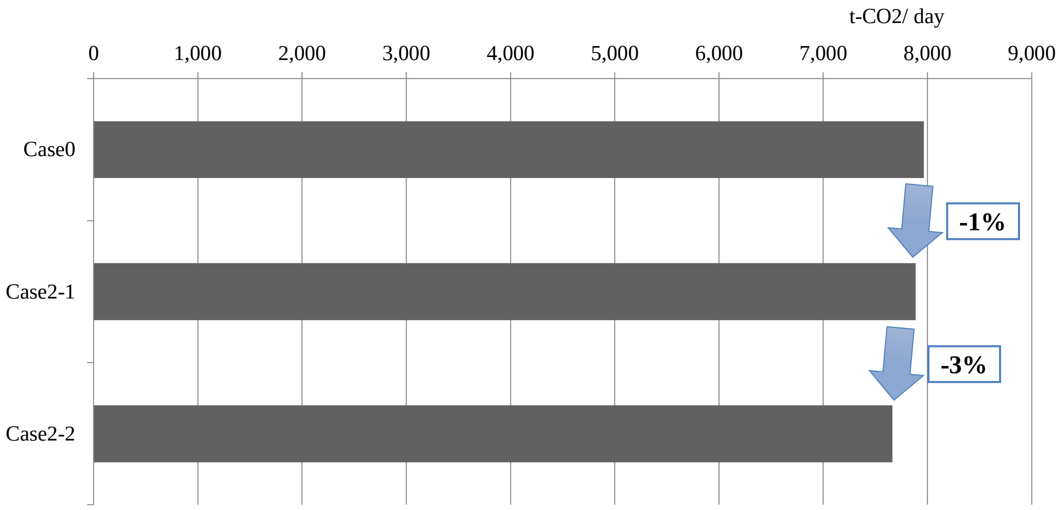

Figure 20. Change of total CO2 emissions

7. CONCLUSION

This research conducted a preliminary analysis based on probe data, calibrated a route choice and implement simulations for several policy scenario in order to reveal the facts of large truck traffic in the TMA and gain insights on how to improve the efficiency of freight transport and urban environment in the TMA.

As a result of the analysis, efficient freight traffic in the TMA has been hindered by the missing links of ring roads and chronic congestion, and that the urban environment may have been deteriorated due to large truck traffic in residential areas. Given so, the results suggest that the construction of roads suitable for large trucks may rationalize and streamline the truck traffic in the TMA, but potentially worsen the living environment and the urban environment as it will decentralize truck traffic. In other words, it is necessary to guide the traffic of large trucks to high standard roads and rationalize and promote the construction of roads suitable for large trucks in order to satisfy both the efficiency of freight transport and improvement of the urban environment in the TMA.

On the other hand, along with the construction of ring roads, the construction of large-scale logistic facilities is advancing, suggesting that the amount of interregional OD of large trucks might significantly change in the future. This research revealed the necessity of a framework for evaluating the location choice of logistic facilities and the traffic of large trucks jointly, though it does not consider the impact of changes in the location of logistic facilities on the traffic of large trucks. By constructing such a framework, the effects of policies relevant to metropolitan logistics can be better evaluated from viewpoints of both transport and land use.

ACKNOWLEDGEMENT

We conducted this research jointly with the Tokyo Metropolitan Traffic Planning Council from 2014 to 2015. We would like to express our deepest gratitude to academic experts, the Ministry of Land, Infrastructure, Transport and Tourism, as well as local governments who shared their many valuable opinions and comments for us to conduct reviews.

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