TRUCK ORIGIN-DESTINATION ESTIMATION USING COMMODITY BASED APPROACH FOR URABN GOODS MOVEMENT *

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1. Introduction

Generally, a model of passenger transportation is basically focused and developed which is much more details than freight transportation. Due to lack of freight's data and a small proportion of freight, they may be main reasons why there is a few researches focusing on freight transportation. However, the interaction among various transportation modes also greatly contributes to the transportation system. A truck origin-destination (O-D) matrix, therefore, is very important since it is one of the key of transportation planning particularly for freight transportation planning.

In general, the truck O-D estimation using both vehicle-trip based and commodity based approaches are formulated to represent the nature of freight transportation. The former focuses on expressing the flows of truck trips which signifies both loaded and empty trips. However, there are two major limitations. Firstly, Holguín-Veras[1)] pointed out that this approach can not consider the important characteristics of the shipments. Additionally, there is no distinction between empty and loaded trips (Holguín-Veras and Thorson[2)]). On the other hand, the latter focuses on the amount of commodities which is being transported. This approach also has a limitation, which is related to their inability to model empty trips. Nevertheless, both approaches can be modeled using traditional four step models.

To obtain the truck O-D, commodity based approach is very interesting since it utilizes the significant behaviors of the freight in the model. There are some researches which attempt to overcome the main disadvantage of this approach considering the empty trip in the model. A very simple method to estimate truck trips from commodity flows is to make use of the average load of transport per vehicle trip or average payload (weight/trip) which represents both empty and loaded trips. For example, Chin and Hwang[3)] proposed to use the maximum likelihood to estimate the truck load factor of the mixture of normal distributions. Hautzinger[4)] then additionally focused on the empty trips of return trip. The commodity flows then is converted to be truck trips using the truck load factor. Holguín-Veras *et al.*[5)] and Holguín-Veras and Thorson[2)] modeled the empty trips from trip chain employing the probability and spatial interaction concept. This study, however, attempts to estimate truck trips using different method. The proposed concept considers both affect from empty trip and the behavior of commodity delivery instead of empty trip only. There are mainly two parts of truck trip conversion including through trips and trip chains which each part consists of empty and loaded trip. The study considers the behavior of loading and unloading commodity in both through trips and trip chains since the characteristics of commodity O-D and tuck O-D are significant different.

This study, therefore, is mainly based on the commodity approach in order to estimate the truck O-D in Tokyo metropolitan area. In addition, the behaviors of freight, particularly trip chains behavior, are incorporated into this study to convert commodity flow to be truck trip based on the Tokyo metropolitan goods movement survey (TMGMS). The proposed model is expected to provide more alternatives and useful results for freight transportation planning. The organizations of this study, therefore, are as follow. Chapter 2 describes the more details of the model concept. Chapter 3 explains the study area. Chapter 4 concludes the study.

2. Commodity based model

The amount of freight measured in any unit of weight such as tons is modeled by commodity based model since it enables the models to capture the fundamental of freight movements more accurately. Normally, this approach is comprised of traditional four steps model as the following process (Holguin-Veras *et al.*[6)]). Firstly, commodity generation stage is to estimate the total commodity weights produced and attracted by each zone in the study area. Secondly, commodity distribution stage is to estimate the commodity O-D flow using gravity models and other forms of spatial interaction models. Thirdly, commodity mode split stage is to estimate the commodity O-D flow of each mode such as light truck and heavy truck. This stage is done by applying discrete choice models or panel data. Finally, traffic assignment stage is to assign vehicle trips to the network. This study, however, makes use of commodity O-D of each vehicle mode directly from TMGMS.

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(1) Truck trip conversion based on commodity flows

The commodity O-D is converted to be truck trips O-D using the characteristics of the freight. The flow chart of the model is illustrated as shown in Figure 1. Additionally, the characteristics of the freight are calibrated using spatial interaction.

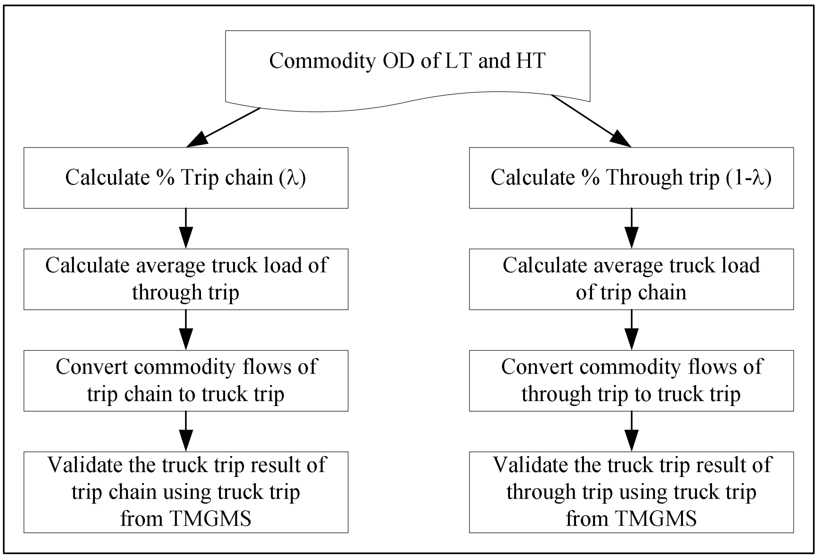

Figure 1: Flow chart of the commodity based model

(2) Parameters calibration

There are three mainly characteristics of freight transportation calibrated from TMGMS as depicted in Figure 2. They are used to convert commodity flows to be truck trips later.

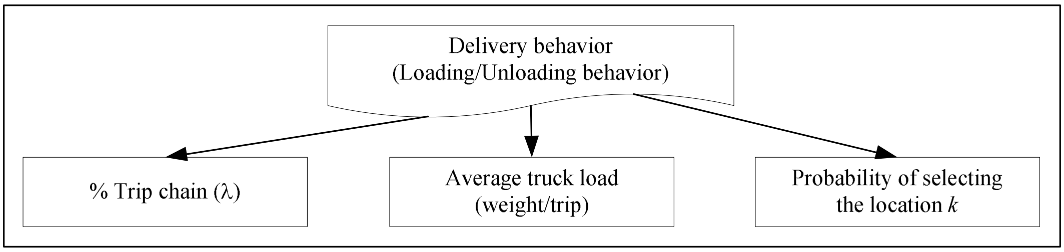

Figure 2: Parameters calibration

a) Trip chain proportion

The truck trips converted from commodity flows carrying by through trips and trip chains are quite different. This study firstly separates the amount of commodity carried by both truck trips using the trip chain proportion. It is assumed to make use the relationship between distance of commodity flow and the trip chain proportion as Equation (1).

$$\lambda_{i,j,ch}^{m,n,v} = \exp(a_{i,j,ch}^{m,n,v} d_{i,j}^{m,n,v}) \tag{1}$$

where $\lambda_{i,j,ch}^{m,n,v}$ represents the proportion of carried goods by trip chain of each OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

$a_{i,j,ch}^{m,n,v}$ represents the parameter of the proportion of trip chain each OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

$d_{i,j}^{m,n,v}$ represents the distance in kilometer each OD pair *ij* of the commodity industry type *m*, goods type *n* and vehicle type *v*

On the other hand, the proportion of through trip is as follow:

$$\lambda_{i,j,th}^{m,n,v} = 1 - \lambda_{i,j,ch}^{m,n,v} \tag{2}$$

where $\lambda_{i,j,th}^{m,n,v}$ represents the proportion of carried goods by through trip of each OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

b) Average truck load

The average truck load is also calibrated from the distance of commodity flow, which is different in each commodity type and industry type as Equation (3).

$$l_{i,j,tr}^{m,n,v} = \exp(b_{i,j,tr}^{m,n,v} d_{i,j,tr}^{m,n,v}) \tag{3}$$

where $l_{i,j,tr}^{m,n,v}$ represents the average truck load of trip type *tr* (through trip or trip chain) between zone *i* and *j* (kg/vehicle) of industry type *m*, goods type n and vehicle type *v*

$b_{i,j,tr}^{m,n,v}$ represents the parameter of the average truck load of trip type *tr* each OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

c) Probability of selecting the next location

The probability of selecting the next location to stop is assumed to vary due to the distance among origin, destination and location of stop. This concept applies to the commodity flows carried by trip chain only since this kind of trip stops at other locations before reach to the destination. However, this model assumes the maximum location of stop between origin and destination as 2 locations as Figure 3. The probability of stop one or two locations is as follow:

$$\mu_1 \sum_i \sum_j \sum_{k_1} p_{i,j,ch}^{m,n,v}(k_1) + \mu_2 \sum_i \sum_j \sum_{k1} \sum_{k2} p_{i,j,ch}^{m,n,v}(k_1,k_2) = 1 \quad (4)$$

where $p_{i,j,ch}^{m,n,v}(k_1)$ represents the probability of trip chain each industry type *m*, goods type *n* and vehicle type *v*, which select location k_1 to stop during OD pair *ij*

$p_{i,j,ch}^{m,n,v}(k_1,k_2)$ represents the probability of trip chain each industry type *m*, goods type *n* and vehicle

μ_1 and μ_2 represent the total probability of each type of trip chain (stop one or two locations), which are determined empirically from the data

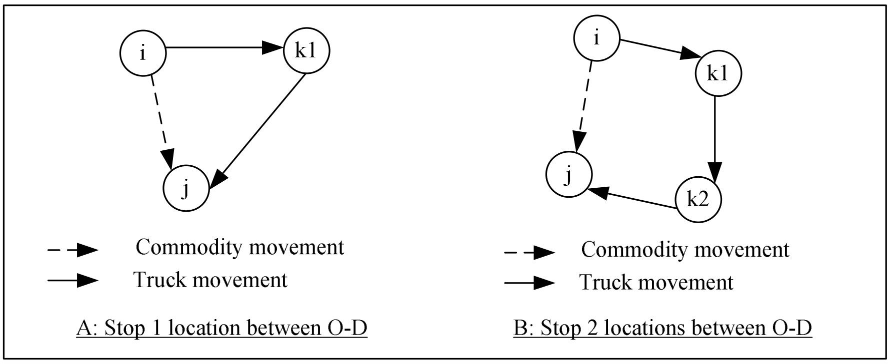

Figure 3: The types of trip chains which stop one or two locations between origin and destination

The probability of selecting location k_1 is calculated from

$$p_{i,j,ch}^{m,n,v}(k_1) = \exp(c_{ch}^{m,n,v} d_{i,k1,ch}^{m,n,v}) \cdot \exp(c_{ch}^{m,n,v} d_{k1,j,ch}^{m,n,v}) \quad (5)$$

$$p_{i,j,ch}^{m,n,v}(k_1,k_2) = \exp(c_{ch}^{m,n,v} d_{i,k1,ch}^{m,n,v}) \cdot \exp(c_{ch}^{m,n,v} d_{k1,k2,ch}^{m,n,v}) \cdot \exp(c_{ch}^{m,n,v} d_{k2,j,ch}^{m,n,v}) \quad (6)$$

where $c_{i,j,ch}^{m,n,v}$ represents the parameter of the probability of selecting location k of trip chain each OD pair ij of industry type m, goods type n and vehicle type v

(3) Solution algorithm based on the through trips

From TMGMS, this study can obtain the aggregate commodity O-D of each industry type, each goods type and each truck size. Then, the amount of commodity carried by through trip is performed as follow:

$$g_{i,j,th}^{m,n,v} = g_{i,j}^{m,n,v} \cdot \lambda_{i,j,th}^{m,n,v} \quad (7)$$

where $g_{i,j}^{m,n,v}$ represents the aggregate commodity O-D (kg) of OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

$g_{i,j,th}^{m,n,v}$ represents the commodity O-D (kg) of OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v* carried by through trip

The truck of through trip, therefore, is computed as follow:

$$t_{i,j,th}^{m,n,v} = \frac{g_{i,j,th}^{m,n,v}}{l_{i,j,th}^{m,n,v}} \quad (8)$$

where $t_{i,j,th}^{m,n,v}$ represents the truck of through trip of OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v*

(4) Solution Algorithm based on the trip chains

The amount of commodity carried by trip chain is performed as follow:

$$g_{i,j,ch}^{m,n,v} = g_{i,j}^{m,n,v} \cdot \lambda_{i,j,ch}^{m,n,v} \qquad (9)$$

where $g_{i,j,ch}^{m,n,v}$ represents the commodity O-D (kg) of OD pair *ij* of industry type *m*, goods type *n* and vehicle type *v* carried by trip chain

Therefore, the truck $t_{i,j,ch}^{m,n,v}$ from trip chain consisting of $t_{i,j,ch}^{m,n,v}(k_1)$ and $t_{i,j,ch}^{m,n,v}(k_1,k_2)$. For example, the trip from Figure 3 represents the trips as follow:

- $t_{i,j,ch}^{m,n,v}(k_1)$ consists of $t_{i,k1,ch}^{m,n,v}(k_1)$ and $t_{k1,j,ch}^{m,n,v}(k_1)$
- $t_{i,j,ch}^{m,n,v}(k_1,k_2)$ consists of $t_{i,k1,ch}^{m,n,v}(k_1,k_2)$, $t_{k1,k2,ch}^{m,n,v}(k_1,k_2)$ and $t_{k2,j,ch}^{m,n,v}(k_1,k_2)$, respectively

Finally, truck trips converted from commodity flows are computes as Equation (8).

(5) Performance of the model

The performance of the model in this study is determined by comparing the results of the model with the observed truck trip from TMGMS.

3. Study area

This study focuses on the urban goods movement using TMGMS data in Tokyo metropolitan area as shown in Figure 4. The study area comprises of 52 zones, 13 industry types, 8 commodity types and 2 types of trucks (light truck and heavy truck). The model concept firstly applies to the commodity type 6 of industry type 7.

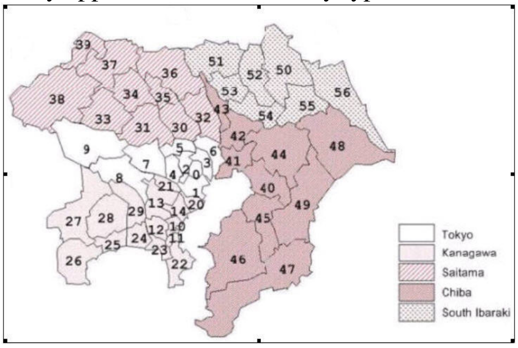

Figure 4: The study area

4. Conclusions

There are three major concepts proposed in this study. Firstly, the truck trip conversion is performed based on commodity approach since it can utilize the important characteristics of freight transportation. Secondly, the model attempts to estimate both loaded trips and empty trip using the concept of through trip and trip chain. Finally, parameters calibration is illustrated and employed to represent the behaviors of freight.

This study, therefore, expects to obtain the truck O-D matrices of both light truck and heavy truck from commodity flows in Tokyo metropolitan area. In addition, the behaviors of freight, particularly trip chains behavior, are incorporated into this study employing the data from TMGMS. The proposed model is also expected to provide more alternatives and useful results for freight transportation planning.

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