AN ANALYSIS OF DELIVERY LOT SIZE AND FREQUENCY BEHAVIOR OF FREIGHT AGENTS FOR A MICROSCOPIC SIMULATION MODEL *

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1. Introduction

A recent global trend for models in transportation planning is to model passenger or freight movements at microscopic level, for reasons that microscopic models deal with individual behavior instead of dealing with zone at the macroscopic level. The microscopic passenger model, which is the so-called "Activity-based" model, has dramatically developed in recent year and left the microscopic version for freight movement far behind. Researchers on freight demand modeling worldwide are trying to catch up; however, freight models are not an easy task. Freight movement has several factors to be considered. First, commodities can come in several forms: varies by shape, weight, and volume. Second, several agents involve in the activities-shippers, customers, freight carriers, and including the administrator who control policies that will affects the activities of the other agents[1]. Finally, surveys conducted on freight movement are quite difficult. Much information that considered improving the model performance, unfortunately, many times cannot be observed because of privacy issue.

Besides all these challenges, there have been several researches with a good attempt for developing freight movement at the microscopic level. For example, INTERLOG[2] in Germany, SAMGODS[3] in Sweden, SMILE[4] in the Netherlands, and the TOKYO[5] models are the outcomes that the researchers around the world are trying to cope with the problems. The characteristics of each model are diverse by the database that they have on hand. However, they share the same concept to apply the knowledge on logistics into the model.

This paper are discussing in the part of the analysis of the delivery lot size and frequency. Microscopic commodity-based models generally deal with the behavior of each single shipment instead of a truck as doing in trip-based models. In the commodity-based model, one might start directly to generate shipments between companies or to follow the traditional four-step modeling style that starting with the generation of commodity production/attraction and commodity distribution before converting to shipments between companies later. The later is the way that this paper selects for the application. The outcomes from the commodity distribution model are the monthly/yearly amount of commodities transferred between companies. The model of delivery lot size and frequency is used to break the commodity flows between companies into an individual shipment that will, later on, assign to a truck with more information likes truck size, carrier type, and delivery route.

The analysis of these issues has found to be a very difficult task since there are several factors related to the decision. First, the decision-maker is not only one but they are shipper and customer. Second, the decision related issue is the costs which are mainly the inventory and transportation costs. The decision depends on who pay for the transportation cost which is considered the main cost. One might say the transportation costs are paid by shipper; however, that cost, in fact, has already included in the price that customer has to pay. Third, the transportation costs vary by several reasons; for example, number of customers that the shipper has in the same area and carrier type that shipper select for the delivery. All these factors make the system to be too complex for a simultaneous analysis.

The location of customers scattering in a space should be considered to affect the decision of delivery lot size and frequency. Models with spatial correlation are widely applied in for the location model such as residential choice which can be found in the works of Bhat and Guo[6], Miyamoto et al[7], and Mohammandian et al[8]. In addition, the shipper location choice in the commodity distribution model has proved success in improving the model performance[9]. This paper proposed that there is a spatial correlation between companies on the decision of delivery lot size and frequency.

This paper provides an analysis of the behavior of delivery lot size and frequency of freight agents in the urban freight movement as one of the part in a microscopic simulation model.

2. Model Structure

(1) Delivery Lot Size and Frequency Model

Assuming that, lot sizes are same at every delivery for each pair of shipper and customer. The delivery lot size, frequency, and monthly commodity flow between a pair of shipper and customer having the following relationship:

$$Q_{ij} = L_{ij} F_{ij} \tag{1}$$

where, Q_{ij} is the monthly amount of commodity flows between shipper *i* and customer *j*. L_{ij} is the delivery lot size of commodity between shipper *i* and customer *j*. F_{ij} = delivery frequency of commodity type *k* between shipper *i* and customer *j*.

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(2) Delivery Frequency Choice Model

The delivery frequency is assumed to be determined first. Later, the delivery lot size is calculated from equation (1) with the given monthly amount of commodity flow. The delivery frequency is constructed based on the discrete choice theory. The choices are based on the Tokyo Metropolitan Goods Movement Survey (TMGMS), 1994 as listed as follows:

Table 1. Delivery Frequency Choice

Choice	Description
1	Twice or more per day
2	Everyday
3	2-3 times per week
4	Every week
5	2-3 times per month
6	Once or less per month

(3) Spatial Part in the Choice Probability

Mohammadian et al.[8] incorporated spatial dependences into a discrete choice model as to explain the housing choice behavior by adding the spatial part into the fixed variables of a spatial mixed logit model. This paper also applies the same concept for the spatial interaction among customers. The specification for the spatial part is based on the inverse distance function. Therefore, the specification of the utility function of a choice of delivery frequency *f* between a pair of shipper *i* and customer *j* is:

$$U_{f,ij} = X_{f,ij}\boldsymbol{\beta} + \phi_{f,ij} + \varepsilon_{f,ij} = \sum_{k=1}^{K} \beta_{f,ij} x_{f,ij} + \lambda \sum_{s=1}^{S} y_{f,s} \frac{1}{d_{js}^{\delta}} + \varepsilon_{f,ij} \tag{2}$$

where, $\beta_{f,ij}$ is a estimated parameter corresponding to the observed characteristic $x_{f,ij}$ of alternative *f* between the pair of shipper *i* and customer *j*. $\varepsilon_{f,ij}$ is the error term of alternative *f*. λ is a scalar unknown parameter. $y_{f,s}$ is the choice of alternative that customer *s* selects when *S* is the total number of customers. d_{js} is the distance between customers *j* and *s*. δ is a scalar unknown parameter.

3. Results

The Tokyo Metropolitan Area (TMA) covering Tokyo, Kanagawa, Chiba, Saitama, and the southern part of the Ibaraki is selected for the case study. The database utilized in this study is from the Tokyo Metropolitan Goods Movement Survey (TMGMS) in 1994 because the latest survey in 2004 has, unfortunately, no information on the delivery frequency. It is better to divide the analysis for each specific type of commodities to consider the characteristic of each of the commodity types. This study divides industry type of companies into 10 types: agriculture, mining, construction, manufacturer, wholesaler, transport/warehouse, retailer, electricity, service, and public office.

Table 2. Estimated parameters

Variables	MUL		Spatial-MUL	
	Parameter	**t-value**	**Parameter**	**t-value**
Distance between shipper and customer				
Dist-C1	-0.0286	-7.76		
Dist-C3	-0.0020	-2.74		
Dist-C4	-0.0036	-5.97		
Dist-C5	-0.0010	-4.48	0.0041	3.69
Correlation Variables				
Distance between customers				
λ			0.0077	1.93
δ			1/4[a)]	
Number of observations	1218		1218	
Log-likelihood at zero	-2182.36		-2182.36	
Log-likelihood at convergence	-2182.3630		-2048.5716	
Adjusted Log-likelihood ratio	0.061		0.133	

Note: [a)] Parameter is constrained to 1/4 for identification purpose

This paper presents the analysis for manufacturers (shipper) delivery to wholesalers (customer). In fact, it is better to divide more the types of commodity; however, the number of samples will be too small for the analysis. This paper therefore retains the classification at this level.

The distance between shipper and customer is selected as an independent variable. On the other hand, the spatial relationship among the customer firms is represented by the distance between zones that the customer firms belong to. The specification is defined using a distance-decay function as shown in (2). The distance is the average travel distance between zones calculated from the traffic survey data.

Table 2 shows the estimation results and compares the values between with and without spatial correlation. Considering the distance between the companies is a specific variable (Dist-C1~C5), the estimated parameters are the values corresponding to each of the choices and the values are to compare with the last choice (Choice 6). The sign of all the parameters are negative. The parameter associated with the highest delivery frequency has the most negative value and less negative with the choice with less delivery frequency. These can be interpreted that, as expected, the longer the distance between the companies, the less the delivery frequency and the larger the delivery lot size between them. After adding the spatial part, the model performance increases significantly (comparing the values of adjusted log-likelihood ratio between the models); while, the other variables become less important. This confirms that the spatial distribution among the customers having great influence in the decision making.

4. Conclusion

This paper proposed a way on the analysis of delivery lot size and frequency by constructing model based on the choice of delivery frequency. The model considered also the spatial interaction between customers since we concern that the customers staying in the nearby area are likely to be delivered at the same time and it is also an indirect way to get the effect from the delivery route. The comparing results with and without spatial correlation shows that the spatial interaction has significant effects on the decision making.

However, the variables considered in the model are quite a few numbers since there are few attributes having from the survey. Conducting a small survey focusing directly on this behavior will be helpful. In addition, the impact from the carrier type which also affect to the transportation cost has not yet considered here. These could be some suggestions on the future research.

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