A STUDY ON THE INFLUENCE OF NETWORK ATTRIBUTES ON THE ROUTE CHOICE BEHAVIOR

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Abstract: Route choice models are widely used for the prediction of passengers and cargo movements by planners. This paper presents the application of a methodology, introduced initially for the prediction of route choice of bicycles, now adapted to motorcycles and trucks. The adaptation of the methodology allowed the improvement of the original analysis algorithm increasing the number of considered network attributes and adding a user related attribute: Value of Time. The case study of truck routes in Tokyo Metropolitan Area produced satisfactory results relating the route choice behavior and the network attributes, especially indicating the relevant attributes to truck trips. As a result, the value of time for trucks in Tokyo and the parameters relating route choice and network attributes were obtained.

Keywords: Route choice model, Route overlapping model, Network attributes, Value of time

1. INTRODUCTION

The route choice behavior of a pedestrian or vehicle driver can be analyzed by several different methodologies which consider different input information and offer different levels of results.

Ideally, computational algorithms that could be capable of selecting the exact path taken by any traveler would provide the solution for route choice prediction. Realistically, algorithms cannot perfectly predict the routes all travelers would choose, due the human complex behavior.

Ramming (2002) comparatively analyzed the replication of paths generated by the most commonly used route choice models: C-Logit, Cross Nested Logit, Logit Kernel, IAP Logit, and Path-Size Logit. In that analysis, one of the main concerns originated from the correction of the overlapping among the route choice set.

The maximum route overlapping methodology avoids this problem by considering the shortest or, here, the cheapest calculated path instead of a set of possible paths. It is usually presented in a form that the actual route length or route cost is compared to the calculated length or cost, and thus used as indicator of overlapping. Although this approach is satisfactory to most studies, it does not assess the level of duplication in the link usage.

Hyodo *et al* (2000) proposed a methodology based on the maximum route overlapping using a duplicate rate of link use as indicator of the model performance. That methodology eliminates the issues related to the route choice set producing a single path as a result of both its iterative process and the single combination of network attributes observed in real networks. In that study, the model was applied to the route choice modeling of bicycles in two Japanese cities.

In this study, the methodology is improved aiming at its application to the route choice modeling of motorcycle and trucks.

The main objective of this study is to evaluate the applicability of that methodology to other vehicles types and different network configurations.

2. THE MODEL: DUPLICATE RATE OF ROUTE OVERLAPPING

The concept of the duplicate rate consists in defining the actual trip length of the *n-th* sample (X_n) as

$$X_n = \sum_a \delta_{na} \times L_a \tag{1}$$

Where:
δ_{na} is a dummy variable (equal to 1 if the *n-th* sample passes the *a-th* link, or zero otherwise);
L_a is the length of the *a-th* link.

Hyodo *et al* (2000) proposed that users may perceive trip lengths differently according to certain link attributes, suggesting the following relationship:

$$L^*_{an}(\beta) = L_a \prod_k \beta_k^{z_{ak}} \tag{2}$$

Where:
$L^*_{an}(\beta)$ is the perceived length of the *a-th* link at the *n-th* sample;
z_{ak} is the *k-th* attribute (e.g. road width) for the *a-th* link of the *n-th* sample;
β_k is the unknown parameter for the *k-th* attribute.

Hence, the definition of the shortest path based on the perceived length takes the form presented in (3).

$$X^*_n = \sum_a \delta^*(\beta)_{na} \times L_a \tag{3}$$

Where:

$\delta^*(\beta)_{na}$ is equal to 1 if the n-*th* sample's perceived shortest paths with parameter β include the a-*th* link, otherwise it is equal to 0.

The duplicate rate D(β) is then introduced as a measure to be fitted, defined as

$$D_n(\beta) = \frac{\sum^{a} \delta_{na} \times \delta^*_{na}(\beta) \times L_a}{X_n} \tag{4}$$

Ramming (2002) defines the replication of the real route in terms of total length or total cost, independent of which links are used by the real route and by the shortest path. Differently, the duplicate rate considers the total length of the coincident links (simultaneously in the real route and in the perceived shortest path using attributes' parameter β).

The duplicate rate ranges from 0 (zero), when links of the shortest path and the links of the real route are not coincident at all; to 1 (one), when the shortest path and the real route are composed by exactly the same links.

In this study, all the route samples will be used to obtain a general set of parameters that maximize the duplicate rate. Therefore, the weighted duplicate rate, which combines the duplicate rate of all the route samples, is defined in (5).

$$D(\beta) = \frac{\sum_n \sum_a \delta_{na} \times \delta^*_{na}(\beta) \times L_a}{\sum_n X_n} \tag{5}$$

The unknown parameters β are, then, arbitrated iteratively in order to maximize the duplicate rate. The maximized D(β) is then named D-value.

2.1 From Shortest Path to Cheapest Path

In this study, the Route Overlapping methodology is applied to two case studies of motorcycles and trucks routes. Differently of the previous studies, which aimed at bicycles routes, the motorcycles and truck drivers are assumed to give priority to the travel cost rather than travel length. Therefore, the main point in this study is the substitution of the perceived shortest path by the perceived minimum cost path in the route overlapping definition.

The Generalized Cost (GC) represents the cost perceived by the user to travel through one link. The form of the Generalized Cost for the *a-th* link is shown in (6).

$$GC_a = (Cons_a + VOT \times Time_a) \times \prod \beta_k^{z_{ak}} \tag{6}$$

The calculation of the generalized cost can be broken in two components: the first, considering the fuel consumption and the travel cost of the link; the second, considering the influence of the link's attributes as in (2).

In the first component, the fuel consumption to travel through the *a-th* link ($Cons_a$) is calculated considering the average engine performance in liters per kilometer traveled, the fuel cost in monetary units per liter, and the link length in kilometers. Also in the first component, the travel cost calculation considers the value of time (VOT) for the user and the estimated time to travel through the *a-th* link ($Time_a$).

In the second component, certain link attributes are represented as dummy variables and their respective parameters in the same form as (2).

The introduction of the generalized cost incorporated an extra parameter in the model, which is related to the users (drivers) rather than to the links, the Value of Time. The introduction of this parameter requires the modification of the general form of the model as shown in (7).

$$D(\beta,\omega) = \frac{\sum_{n} \sum_{a} \delta_{na} \times \delta^{*}_{na}(\beta,\omega) \times L_a}{\sum_{n} X_n} \tag{7}$$

where $\delta^{*}_{na}(\beta,\omega)$ is equal to 1 if the *n-th* sample's perceived minimum cost paths (for network parameters β and value of time parameter ω) include the *a-th* link, otherwise it is equal to 0.

3. ESTIMATION OF PARAMETERS

The process of estimation was based on the previous study, where the parameters for bicycles' route choice were arbitrated within pre-defined limits. The parameters resulting in the highest duplicate rate were, then, stored.

The previous study considered no more than three parameters simultaneously, and, using a genetic algorithm application, up to 4 parameters. In this study, a new algorithm made possible the simultaneous evaluation of up to 7 parameters.

The algorithm used here consists of the increasingly arbitration of the parameters, from a lower pre-defined limit to a higher pre-defined limit, according to a defined increment.

This process, although simple, may require significant processing time depending on the number of parameters to be evaluated, the increment resolution (for example: 0,1 or 0,0001), and the quantity of route samples. However, it provides a rather broad view of the influence of each attribute on the route choice model.

4. MOTORCYCLE ROUTES IN HO CHI MINH CITY

The evaluation of the Maximum Route Overlapping methodology in Ho Chi Minh City (HCMC) was based on a sample of 167 motorcycle routes obtained in 2003, for the Study on Urban Transport Master Plan and Feasibility Study in Ho Chi Minh Metropolitan Area (HOUTRANS).

HCMC was selected due to the high share of motorcycles in the urban traffic, around 90%, according to Matsuhashi *et al* (2005).

The network data, composed by 1819 nodes and 4866 links, as shown in Figure 1, provided 12 possible attributes for the links. From those, three attributes were selected initially to the application of the methodology: speed limit, road width, and pavement type. The other attributes were considered to be interrelated. After the analyses, the pavement type was removed. It has not influenced the duplicate rate of route overlapping. Table 1 presents the three criteria defined according to the selected attributes.

Two different analyses were performed: single parameter estimation and multi-parameter estimation. The first considered the variation of each parameter individually and its impacts on the duplicate rate. The second considered the simultaneous variation of all parameters and their impact of the on the duplicate rate.

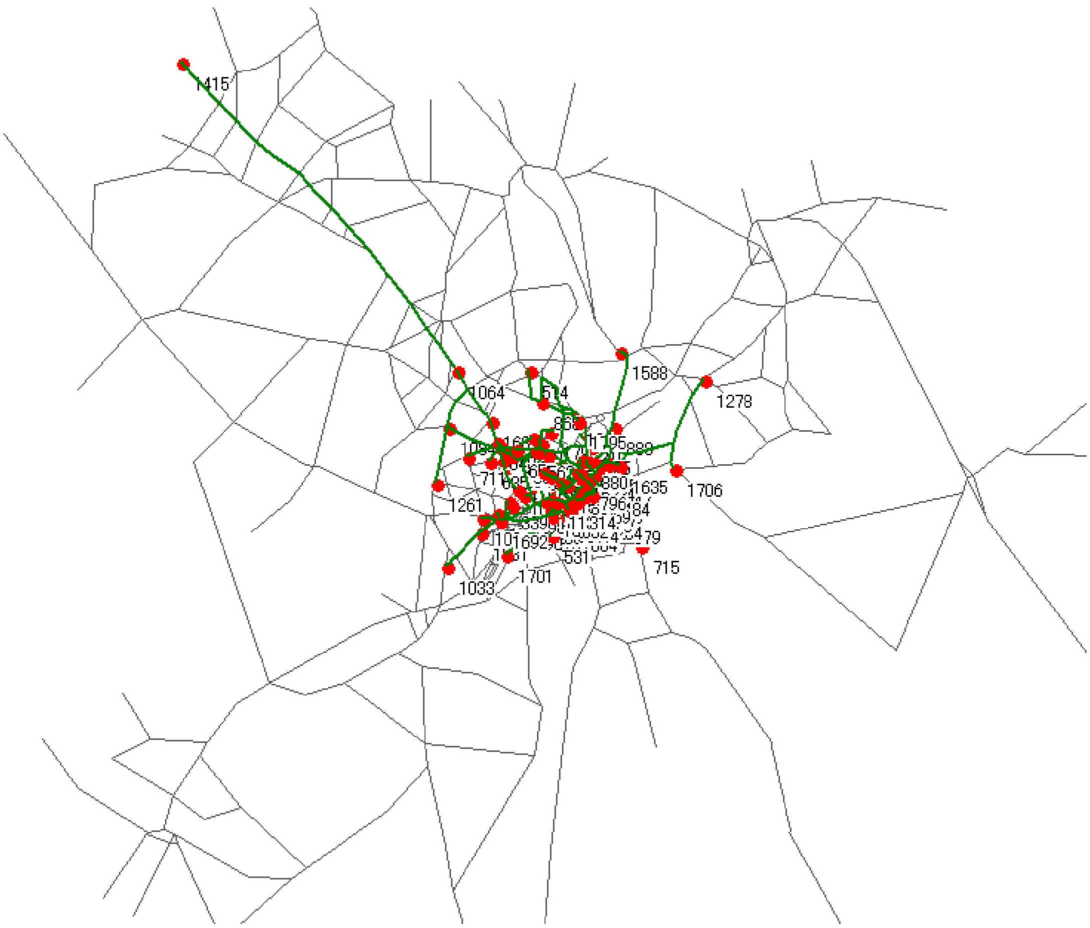

Figure 1 Network and route samples in Ho Chi Minh City

Table 1 Criteria of Attributes for Ho Chi Minh City

	Attribute	Condition for $\beta_{na} = 1$	Condition for $\beta_{na} = 0$
1	speed limit	> 40 km/h	otherwise
2	road width	> 3.0 m	otherwise

The results for the single parameter estimation are presented in Figure 2. The variation of the Value of Time showed no influence to the route choice behavior in Ho Chi Minh City. The duplicate rate kept constant at 0.397252 for all the arbitrated parameters of value of time (from 0 to 100).

The results represented in Figure 2 indicate a higher influence of the attribute speed limit over the other attributes. Similar to the Value of Time, the attribute pavement type have not influenced the duplicate rate.

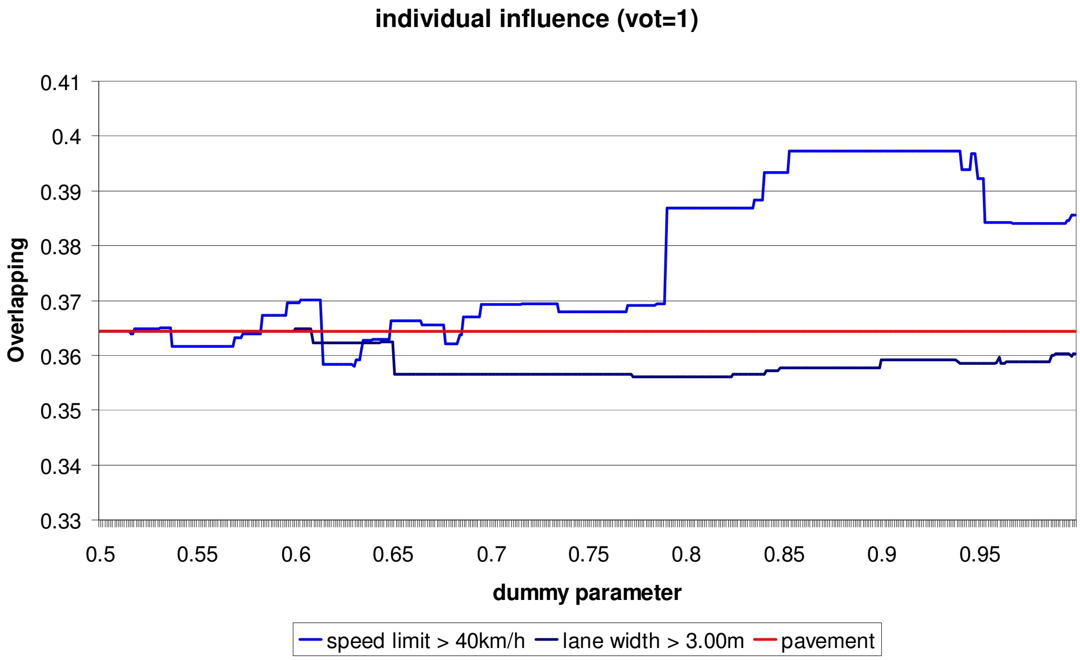

Figure 2 Individual estimation of parameters for Ho Chi Minh City

The simultaneous variation of all parameters can indicate how the parameters relate to each other to influence the duplicate rate of overlapping route. In the case study 1, as shown in Figure 3, the maximum duplicate rate is not influenced by the combination of the attributes.

5. TRUCK ROUTES IN TOKYO

The sample for Tokyo represents 597 routes of trucks, in a network composed by 9231 nodes and 25062 links, as shown in Figure 4.

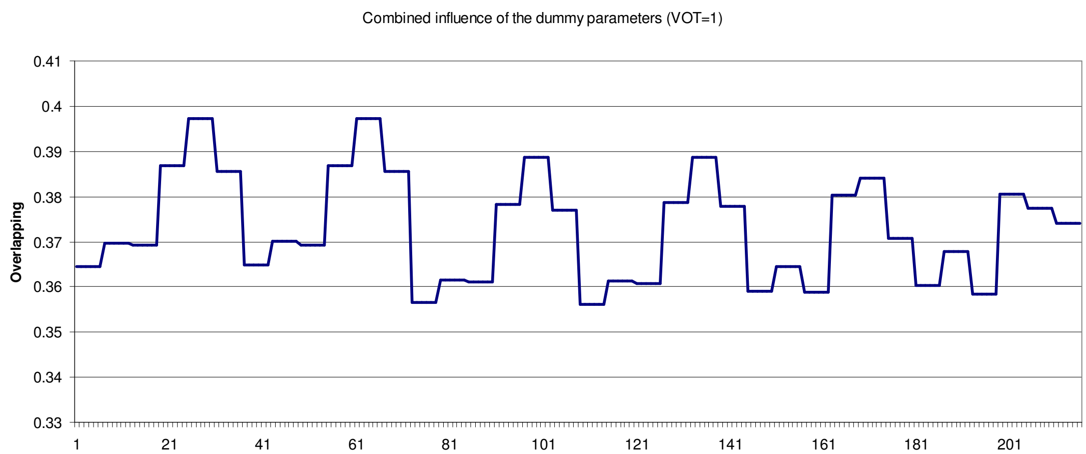

Figure 3 Simultaneous estimation of parameters for Ho Chi Minh City

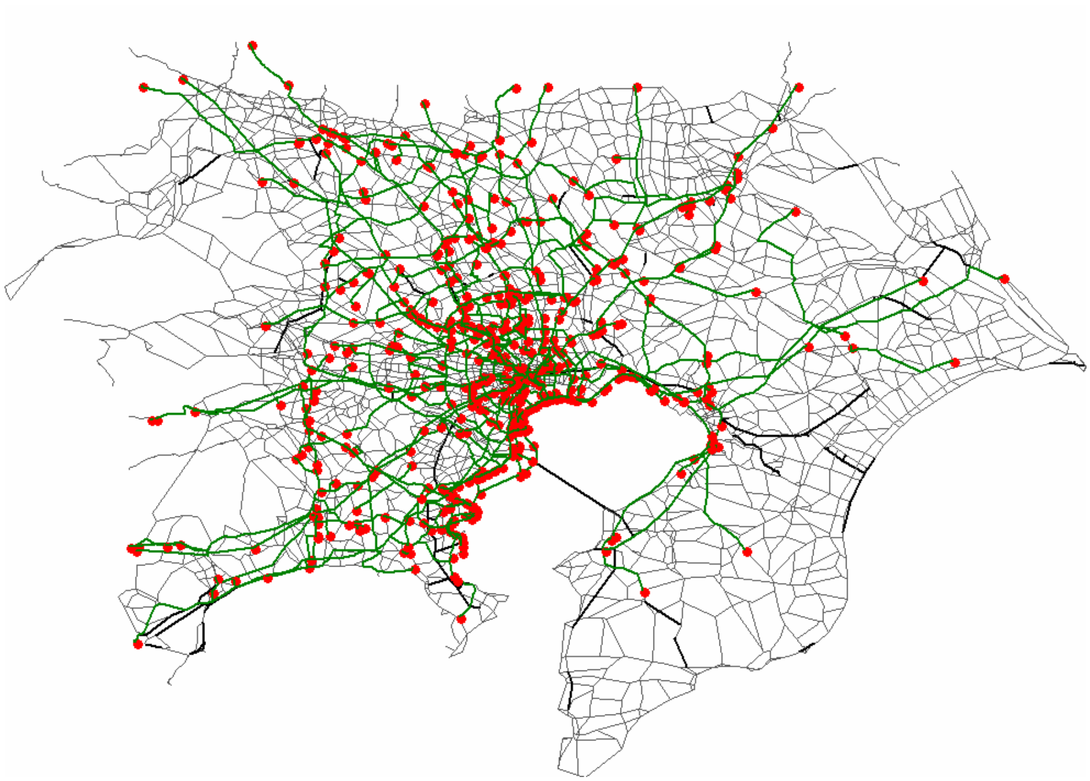

Figure 4 Network and route samples in Tokyo

The attributes of the links were selected considering the results of Matsuhashi (2005), where the parameters of the link's attributes available in the route sample were evaluated individually in order to identify the most significant conditions. The attributes used to estimate the duplicate rate are presented in Table 2.

Table 2 Criteria of Attributes for Tokyo

	Attribute	Condition for $\beta_{na} = 1$	Condition for $\beta_{na} = 0$
1	Tolled road	tolled link	otherwise
2	CBD area	inside CBD area	otherwise
3	Ring Road 7	inside ring road7	otherwise
4	Number of lanes	= 4 lanes	otherwise
5	Heavy truck permission	yes	otherwise
6	Tall truck permission	yes	otherwise

The attributes 5 and 6 refer to the restrictions to weight and height in the roads within the Tokyo Metropolitan Area. Those attributes are directly related to the possible trucks' routes, therefore expected to have significant influence in the route choice model. Figures 5 and 6 show the links where heavy trucks and tall trucks are permitted, respectively.

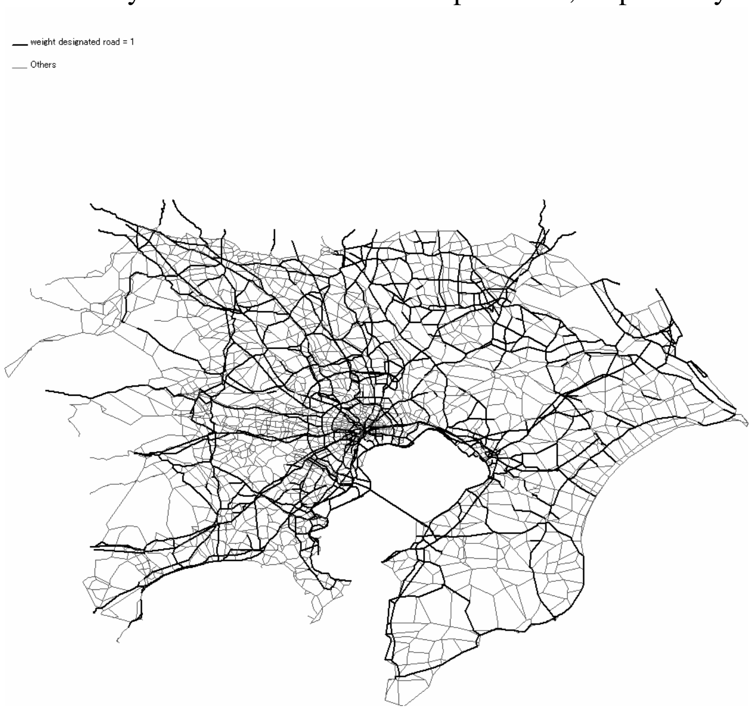

Figure 5 Heavy trucks permitted links in Tokyo

Similar to the parameter estimation for HCMC, the procedure was performed considering the individual and simultaneous variation of the parameters.

The first aspect to be considered in the route overlapping estimation is the variation of the value of time. Prior studies have pointed to an average VOT between JPY 50 and JPY 200 per minute, depending on the vehicle type. These values are used in this study as the limits for the value of time variation. All other dummy variables were kept constant (equal to 1) for this estimation.

The estimation of the network related parameters must be related to the value of time estimation since this presents a strong influence on the maximum duplicate rate. The results for the estimation of each individual parameter in association to the Value of Time are shown in Table 3.

Figure 6 Tall trucks permitted links in Tokyo

The simultaneous estimation of the parameters showed a strong interrelation among the attributes, reflected in the maximum duplicate rate achieved. As Table 4 shows, the duplicate rate obtained by the combination of the attributes was higher than the obtained by the individual attributes.

The sample data set included the classification of the vehicles in two types. The two types correspond to container trailers and other trucks. Considering that container trailers have more restrictions to urban traffic than other types of trucks, the two types were separated and the multi-parameter estimation was once more conducted. The results indicate that significantly higher duplicate rates can be obtained by the appropriate characterization of the sampled vehicles. Table 5 and Table 6 show the results for the container trailers and for the other types of trucks, respectively.

The results for the container trailers indicate a significantly lower value of time for this type of vehicle. Moreover, the parameters indicate that routes chosen by container trailers are influenced mainly by the roads' restrictions of weight and height.

The results for the other types of trucks, Table 6, indicate influence from the other attributes such as tolled roads and number of lanes.

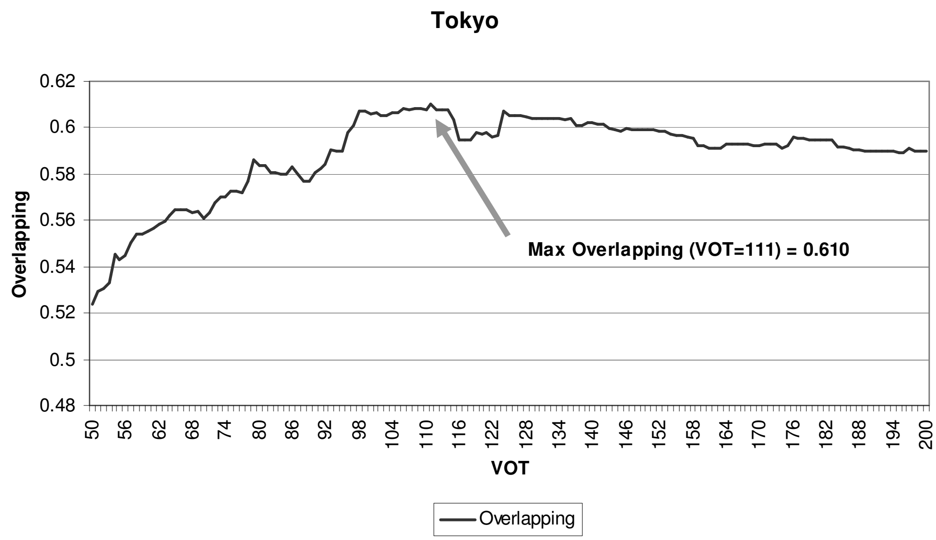

Figure 7 Estimation of Value of Time (JPY/min) for Tokyo

Table 3 Individual Parameters for Trucks in Tokyo

Attribute	Parameter	Duplicate rate
VOT Tolled road	73 0.710	0.632959
VOT CBD	98 0.990	0.607072
VOT Ring Road 7	98 0.995	0.607312
VOT 4 lanes	106 0.785	0.642533
VOT Weight	75 0.600	**0.650342**
VOT Height	95 0.600	0.645822

Note: Value of Time (VOT) in JPY/min

Table 4 Combined Parameters for Trucks in Tokyo

Attribute	Parameter	Duplicate rate
VOT Tolled road CBD Ring Road 7 4 lanes Weight Height	97 0.9 0.8 1.0 0.9 0.8 0.6	0.670913

Note: Value of Time (VOT) in JPY/min

Table 5 Combined Parameters for Container Trailers in Tokyo

Attribute	Parameter	Duplicate rate
VOT	14	
Tolled	1.0	
CBD	1.0	
RingRoad7	1.0	0.669285
4 Lanes	1.0	
Weight	0.8	
Height	0.9	

Note: Value of Time (VOT) in JPY/min

Table 6 Parameters for Non-Container Trailer Trucks in Tokyo

Attribute	Parameter	Duplicate rate
VOT	90	
Tolled	0.6	
CBD	1.0	
RingRoad7	0.9	0.803336
4 Lanes	0.6	
Weight	0.8	
Height	0.7	

Note: Value of Time (VOT) in JPY/min

6. CONCLUSIONS

The main conclusions of this study are related to the applicability of the maximum route overlapping methodology.

The adaptation of the methodology to consider the perceived route cost rather than the perceived route length was successful. As a result of this adaptation, an alternative process for the estimation of the value of time was presented. This process is especially interesting for indicating that value of time is an influential parameter to the route choice model only in the presence of tolled roads (which represent the expressway system).

The utilization of different increment resolutions (e.g. 0.1 or 0.001) implies in refinement of the maximum duplicate rate, which will be subject to a sensibility analysis to identify the level of impact in an all-or-nothing assignment in the next steps of this research.

The results of the analysis of motorcycles routes in Ho Chi Minh City indicate that some attributes do not interact when influencing the route choice behavior, specifically in the case of motorcycles. Further researches should attempt to identify which attributes significantly influence the route choice behavior of motorcycles.

The analysis of the truck routes in Tokyo indicate that truck route choice behavior is significantly influenced by several attributes, mainly for those representing the limitations imposed by the network to the larger sizes of trucks. Moreover, the maximum route overlapping methodology has successful estimated the value of time for the truck routes. Also, the results of this case study suggest that route choice behavior for freight transportation may be influenced by the type of trucks. These results also suggest that an assignment procedure that considers vehicle type based route choice models are sound and coherent, and, therefore, will be considered in the next steps of this research.

The iterative nature of this methodology requires the improvement of the shortest path search algorithm in order to reduce computation time and possibly permit the introduction of a higher number of attributes and higher increment definition.

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