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Modelling Route Choice Behaviour of Non-Motorized Transport

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Abstract: Given the thrust to pursue environmentally sustainable modes of transport, non-motorized transport, such as cycling and walking, are strategies that are always considered. However, given the cognitive nature of non-motorized transport, specifically the "cycler" and the "walker", it is important to understand and consider the route choice behaviour of both in coming up with transportation plans and implementing transportation infrastructure improvements. This paper aims to understand the route choice behaviour of non-motorized transport by utilizing the Maximum Overlapping Ratio Model in developing the route choice behaviour model of non-motorized transport. Using route choice survey data gathered and road characteristics of the study area as inputs into the model, the effect of certain characteristics and features of roads on the route choice behaviour of non-motorized transport is examined. Finally, using the result of the route choice behaviour model, a simulation of the effect of improving road infrastructure is conducted.

Keywords: Route Choice Behaviour, Maximum Overlapping Ratio Model, Non-Motorized Transport, Walking, Bicycles

1. INTRODUCTION

The world is transitioning to more environmentally sustainable modes of urban transport and this gives rise to the thrust for smarter mobility, which increase plans for the implementation of not only hybrid/low emission technology transport but also the implementation of facilities for non-motorized transport. This is also another approach in developing low carbon societies or cities.

In conducting studies on non-motorized transport, cycling and walking are usually treated as a single mode of transport due to the fact that both are powered by muscle, has no protection from the bodywork of a vehicle, and is open to the surrounding environment (Parkin, 2010). But it is argued that the difference in mean speed between cycling and walking (22 km/h for cycling compared with 4 to 5 km/h for walking) is so great that these two modes should never be treated as a homogenous whole (Parkin, 2010). However, this paper considered cycling and walking as a single mode of transport due to the limitation of the survey data wherein cycling and walking were not disaggregated. Notwithstanding the argument that cycling and walking should not be considered as a whole, it is justified that cycling and walking can be considered as a single mode of transport or generally as non-motorized transport when viewing it from a perspective that non-motorized transport is mostly considered an access or feeder mode of transport to public transport as well as a last mile mode of transport from a public transport terminal to the final destination.

In this paper, using data collected from an actual route choice survey, a modelling of route choice behaviour of non-motorized transport in Shizuoka City will be done in order to understand variables that significantly influence route choice behaviour of non-motorize transport users. It is also the aim of this paper to propose a method of forecasting route choice behaviour of non-motorized transport through a heuristic method utilizing the Maximum Overlapping Ratio Model developed by Hyodo *et al.* (2000). Subsequently, a simulation using the formulated model will be done in order to identify the effects on route choice of pedestrian and bicycle traffic of the possible improvements to Shizuoka City's road network.

1.1. Review of Related Literature

Existing research have tried to understand what motivates mode shift to non-motorized transport due to, for instance, increasing congestion in vehicular roads. To further understand the behaviour of non-motorized transport, various research also tried to analyse and model non-motorized route choice to gain information on what influence walkers and cyclist in choosing a specific route. For instance, cities that are investing in bicycle infrastructure are faced with decisions of where to invest and what type of facility to install, e.g. bike lanes or separate paths (Broach, Dill, & Gliebe, 2012). Furthermore, very little is known about how far people actually walk or about how street design affects people's willingness or capacity to access desired destinations on foot (Agrawal, Schlossberg, & Irvin, 2008).

Much of the research on route choice of non-motorized transport utilize the stated preference (SP) survey where SP surveys ask respondents to rank or rate their preferences for different types of facilities; on the other hand, revealed preference (RP) studies have also been undertaken on route choice, but in general they are limited studies that do not estimate a full route choice model (Broach, Dill, & Gliebe, 2012) meaning a set of routes is chosen for the analysis. SP survey-based studies are relatively easier and less costly to conduct because the survey questionnaire can be constructed using finite and predetermined routes that respondents can choose from whereas RP based surveys can be costlier and tedious to conduct as the survey questions will entail the recording of the actual routes taken by the respondents. This study utilized data from an RP survey conducted in Shizuoka City where respondents were asked to trace the routes they usually take from an origin to destination along with the usual trip survey questions (e.g., origin, destination, and purpose).

Studies examining route choice can be classified in to two broad categories: (1) aggregate-level studies and (2) disaggregate-level studies where aggregate-level studies focus on analysing the relationship between route characteristics and aggregate use measures on the routes (such as change in volume after using a route after improvements) whereas disaggregate-level studies undertake the analysis at the level of individuals (Sener, Eluru, & Bhat, 2009). However, the analysis of travel behaviour is typically disaggregate, meaning that the models represent the choice behaviour of individual travellers (Ben-Akiva & Bierlaire, 1999) and as such, this paper aims to examine route choice on a disaggregate level..

Route choice studies are conducted using deterministic traffic assignment models such as the family of Generalized Extreme Value (GEV) models proposed by McFadden (1987) which includes the well-known Multinomial Logit (MNL) and Nested Logit models which are based on the Gumbel distribution, and the Multinomial Probit (MNP) which is based on the assumption that the error terms are normally distributed. Broach, Dill & Gliebe (2012) for instance modelled bicycle route choice behaviour in Portland, Oregon, USA using the Path-Size Logit (PSL) model utilizing revealed preference GPS data. Bekhor, Ben-Akiva, &

Ramming (2006) discussed choice set generation and route choice model estimation for large-scale networks and the ability of different route generation algorithms to produce paths similar to those observed and presented estimation results of two route choice models. This paper however will suggest a methodology in modelling non-motorized transport through a heuristic method that utilizes the concept of overlapping links based on a *cognitive minimum path* which is defined in the preceding sections.

2. OVERVIEW OF STUDY AREA AND SURVEYED DATA

2.1. Characteristics of Shizuoka City

Shizuoka City is the capital city of Shizuoka Prefecture, Japan with an area of 1,411.93 km^2 and total population of 715,752 as of the end of December 2014. The main feature of Shizuoka City used in this paper are the road network and the basic characteristics of the roads (i.e., road width, presence of sidewalk on either side or both, has a break/interruption in the sidewalk, and whether it is a community road or not). It must be noted that traffic signals are not included in the road characteristics. It is because the road network data used in the study does not include such information. This may not impact the study significantly as by examining the network structure of the study area, there are only few wide roads and intersections that could affect bicycle and pedestrian route choice. This is unlike areas in Tokyo where numerous wide roads and intersections in which traffic signals clearly influence route choice as not only is it difficult to cross intersections with traffic signals but there are also sign that directs bicycles and pedestrians where to pass through. The elements used to represent the features of Shizuoka City's road network are nodes and links generated through the use of coordinates of both ends of a link in Shizuoka City's roads. Further, the links contain information on the basic characteristics of roads mentioned above. Figure 2 to Figure 5 visualize Shizuoka City's road network by the abovementioned basic characteristics.

A community road is primarily designed for pedestrians and bicycle users but does not necessarily restrict the passage of cars. Community roads are distinguished from ordinary roads with the presence of structures, equipment, traffic rules as well as the road design itself (e.g., chicanes, woonerf, etc.) that reduce the speed of cars.

Figure 1 Road network of the study area

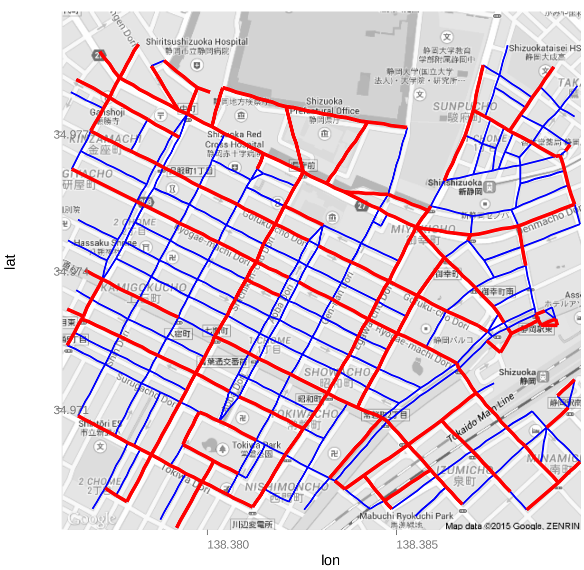


Figure 2 Roads that have sidewalks on both sides

Figure 6 Roads that have sidewalk only on the left-side

Figure 5 Roads that have sidewalk only on the right-side

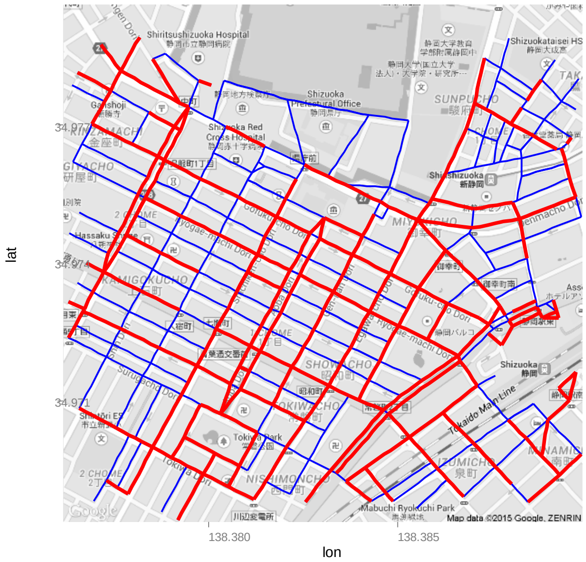


Figure 3 Sidewalks has no breaks/is continuous

Figure 4 Road is a community road

2.2. Shizuoka City Person-Trip Survey

A household interview survey (HIS) was conducted in 2010 to understand the travel behaviour of people in Shizuoka City. The route choice data collected was an "Add On" survey of the HIS. It consists of the basic profile of a traveling person (i.e., sex, age, type of job, type of license, if he/she has owns a car or a bike and what kind, trip purpose, and the paths traversed within Shizuoka City). The HIS data will be especially useful in this study by utilizing as inputs, in the formulation of the route choice model, the route choice data collected in the "Add On" survey of the HIS. However, as mentioned above, cycling and walking were considered as a single mode of transport (as non-motorized transport) due to data restrictions wherein the "Add-On" survey did not distinguish cycling and walking as separate modes of transport when the survey was conducted thus rendering it impossible to separate the two from the collected data. Furthermore, during the time when the HIS and "Add-On" survey was conducted, there were no known future plans from Shizuoka City government to separate bicycles from pedestrians and hence the survey was conducted as such. Though it is a fact that according to national and local laws in Japan, bicycles must travel along roads and not on sidewalks because bicycles are classified as light vehicles according to Japan transportation laws, it is also evident that this specific policy is not being strictly followed by the people as can be observed on the ground hence it is sufficient to say that there is a mix of bicycles and pedestrians in sidewalks at least in Japan

3. ROUTE CHOICE MODEL OF NON-MOTORIZED TRANSPORT

3.1. Model Formulation using the Maximum Overlapping Ratio Model

In this paper, a two attribute route choice model for non-motorized transport will be developed by applying the Maximum Overlapping Ratio (MOR) Model.

First, the actual trip length of the *n* th sample, X_n, from the person-trip survey is defined as

$$X_n = \sum_a \delta_{na} \cdot l_a, \tag{1}$$

where

δ_{na} : dummy variable (if the *n* th sample passes the *a* th link, δ_{na} is equal to 1; otherwise, δ_{na} is equal to 0)

l_a : length of the *a* th link

Next, the cognitive length of the *a* th link is defined as

$$l^*_{an}(\beta) = l_a \cdot \prod_k \beta_k^{z_{ank}}, \tag{2}$$

where

$l^*_{an}(\beta)$: cognitive length of the *a* th link of the *n* th sample

z_{ank} : dummy variable for *k* th attribute for the *a* th link of the *n* th sample

β_k : parameter of *k* th attribute to be estimated $(0 \leq \beta_k \leq 1)$

A cognitive length is defined as the perceived length of a link based on the assumption that the length of a link may be perceived as shorter based on its characteristics/ attributes. Further, the parameter, β, determines the degree to which the length of a link is perceived based on its associated variable, i.e., a high β value means that the perceived length of a link is closer to its actual length; and a low β value means that the perceived length of a link is relatively lower than its actual length. As it is the aim of this paper to develop a two attribute route choice model, equation (2) above will be further defined as

$$l^*_{an}(\beta_1, \beta_2) = \beta_1^{z_{an1}} \cdot \beta_2^{z_{an2}} \cdot l_a, \tag{3}$$

Having defined the cognitive length of a link, the cognitive minimum path of the *n* th sample based on parameter β, $X^*_n(\beta)$, is now defined as

$$X^*_n(\beta) = \sum_a \delta^*_{na}(\beta) \cdot l_a, \tag{4}$$

where $\delta^*_{na}(\beta)$ is equal to 1 if the *n th* sample's cognitive minimum path with parameter β includes the *a* th link, otherwise $\delta^*_{na}(\beta)$ is equal to 0. The cognitive minimum path is understood as the links traversed by the *n* th sample assuming that the links exhibit the characteristics/attributes that affect a link's cognitive/perceived length. This may also be called the *cognitive shortest path* or the *perceived shortest path* of the *n* th sample based on some link characteristic/attribute.

Next, the overlapping ratio is introduced as a measure to be fitted. The overlapping ratio is defined as

$$D_n(\beta) = \frac{\sum_a \delta_{na} \cdot \delta_{na}^*(\beta) \cdot l_a}{X_n}, \qquad (0 \leq D_n(\beta) \leq 1) \tag{5}$$

The numerator is the sum of the lengths of the links that are included in both the actual route taken as well as in the cognitive minimum path determined based on the estimated parameter. Thus, a link l_a is included if both δ_{na} and $\delta_{na}^*(\beta)$ are equal to 1. The denominator is the length of the actual route taken. Thus, if the overlapping ratio approaches a value of 1, the model being developed is representing the behaviour of the sample well.

Finally, in order that the parameters for all samples may be estimated, a weighted overlapping ratio will be applied using the actual trip length for the *n* th sample as defined in equation (1) above. The resulting equation is as follows:

$$D(\beta) = \frac{\sum_n X_n \cdot D_n(\beta)}{\sum_n X_n} = \frac{\sum_n \sum_a \delta_{na} \cdot \delta_{na}^*(\beta) \cdot l_a}{\sum_n X_n} \tag{6}$$

Thus, equation (6) above is the objective function that will be maximized in order to estimate the parameters β of the attributes of the links. The succeeding section will discuss the estimation process used. Figure 7 illustrates that components of the MOR model.

3.2. Estimation of Model Parameters

The parameters, β, are estimated by maximizing the resulting objective function, $D(\beta)$, from the preceding subsection where the route choice model was formulated. However, road network statistics are generally discrete in nature. Thus, equation (6) above cannot be differentiated with respect to parameters, β. Therefore, a heuristic approach to estimating the parameters, β is proposed by utilizing the estimation method applied by Hyodo *et al.* (2000) for single-variable parameter estimation which rely on visualizing the result in order to identify the real maximum from local maximums. Figure 8 illustrates the parameter estimation process.

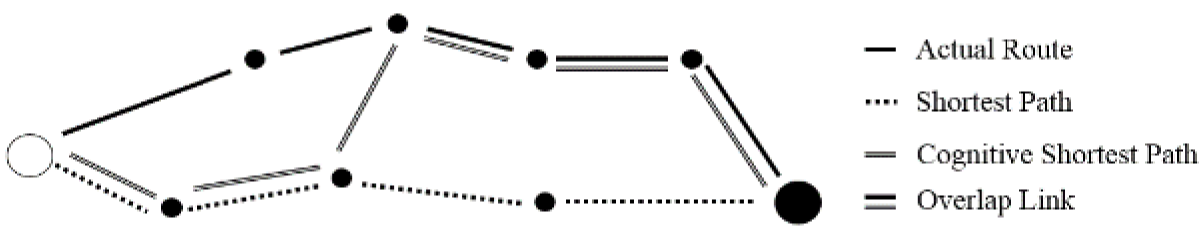


Figure 7 Illustration of model definitions

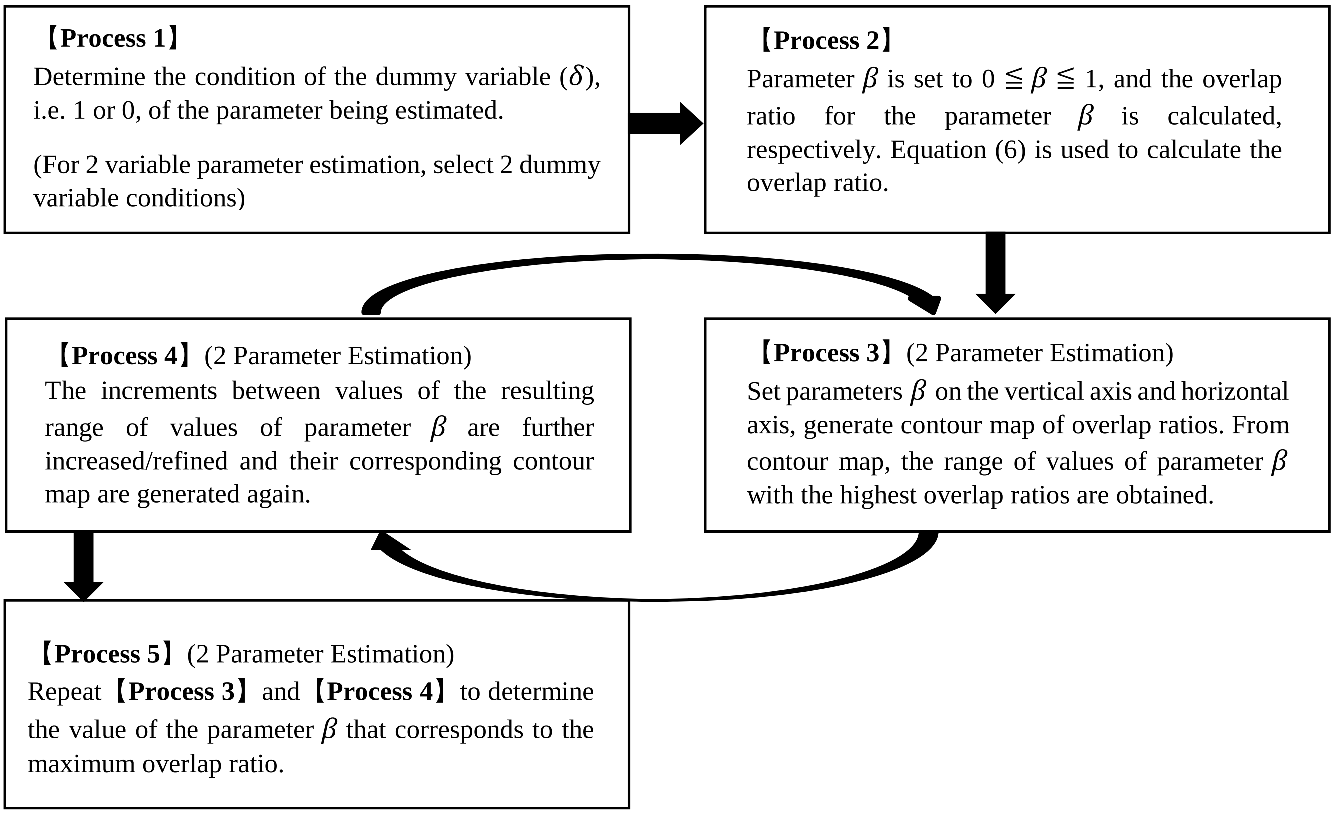


Figure 8 Parameter estimation process

3.2.1. Single parameter estimation

Before proceeding to the two parameter estimation process, a single-variable parameter estimation will initially be conducted in order to determine initial values for the succeeding two-variable parameter estimation process. There are nine variables to consider based on the road data utilized for this study, however, exhausting all combinations of variables will be impractical as it will exponentially increase the calculation time rendering the estimation process inefficient. Thus, a single-variable parameter estimation is deemed necessary in order to select the variables that will be subjected to two-variable parameter estimation. Through this, the variables that will be considered in the two-variable parameter estimation have already been reduced providing for a more efficient estimation process. The results of the single-variable parameter estimation are shown in Table 1 to Table 3.

Table 1 Results of the Road Width Dummy Variable

	Initial Overlap Ratio	0.494
Dummy Variable (Road Width)	**Parameter (β)**	**MOR**
above 9m	0.9	0.517
above 10m	0.89	0.518
above 11m	0.89	0.531
above 12m	0.9	0.531
above 13m	**0.81**	**0.533**
above 14m	0.81	0.528
above 15m	0.92	0.501

Based on Table 1, the dummy variable for “road width is above 13m” yielded the lowest estimated parameter (0.81) as well as the highest MOR (0.533). Thus, it may be inferred that such roads may be perceived as shorter and have a higher chance of being selected by non-motorized transport.

Table 2 Results of the Sidewalk Width Dummy Variable

	Initial Overlap Ratio	0.494
Dummy Variable (Sidewalk Width)	**Parameter (β)**	**MOR**
above 1m	0.8~0.81	0.515
above 2m	0.89	0.516
above 3m	0.89	0.529
above 4m	0.9	**0.553**
above 5m	**0.81**	0.551

Though it is observed in Table 2 that the sidewalk width dummy variable “above 4m” yielded the highest MOR (0.553), it is only 0.002 higher than the MOR (0.551) of the sidewalk width dummy variable “above 5m.” Thus, the difference between the MORs are negligible. Further, the lowest estimated parameter (0.81) came from the sidewalk width dummy variable “above 5m”, thus, it may also be inferred that sidewalks with width of 5m may have a higher influence on the cognitive distance of a link than sidewalks with width of 4m. Therefore, both variables will be considered in the succeeding two-variable estimation process.

Table 3 Results of the Road Characteristic Dummy Variable

	Initial Overlap Ratio	0.494
Dummy Variable	**Parameter (β)**	**MOR**
Road has sidewalk on right side	0.79	0.502
Road has sidewalk on left side	0.99	0.496
Road has sidewalk on both sides	0.76	0.502
Road has no sidewalk	1	0.494
Sidewalk has no breaks/ is continuous	**0.61**	0.539
Road is a community road	0.79	**0.549**

Based on Table 3, the MOR (0.549) is highest with dummy variable “Road is a community road.” On the other hand, the estimated parameter (0.61) is least with the dummy variable “Sidewalk has no breaks/ is continuous.” Further, it is also observed that the MOR (0.539) for the dummy variable “Sidewalk has no breaks/ is continuous” is sufficiently high compared to most of the MORs. Thus, both “Road is a community road” and “Sidewalk has no breaks/ is continuous” will be considered in the two-parameter estimation process.

3.2.2. Two parameter estimation

Having determined in the preceding subsection the variables that will be considered, the two-variable parameter estimation can now be conducted. The same estimation process as the single-variable parameter estimation process will be utilized, however, the formula of the cognitive length will now be equation (3) as developed in the previous section. Table 4 below shows the combinations of dummy variables that will be used in the two-variable parameter estimation.

Table 4 Combinations of Dummy Variables

Combinations	**Road width above 13m**	**Sidewalk width is above 4m**	**Sidewalk width is above 5m**	**Sidewalk has no breaks/ is continuous**
Road width is 13m or more				
Sidewalk width is above 4m	Dummy Variables (1)			
Sidewalk width is above 5m	Dummy Variables (2)			
Sidewalk has no breaks/ is continuous	Dummy Variables (3)	Dummy Variables (5)	Dummy Variables (7)	
Road is a community road	Dummy Variables (4)	Dummy Variables (6)	Dummy Variables (8)	Dummy Variables (9)

*The combination of "Sidewalk width is above 4m" and "Sidewalk width is above 5m" is excluded because this combination is redundant as both are sidewalk attributes.

However, for practicality, only the top five (5) results of the two-variable parameter estimation, i.e. combinations that yielded relatively high MORs, will be presented. Figure 9 to Figure 13 below illustrates the top five (5) results of the two-variable parameter estimation. Also, Table 5 to Table 9 presents the results of both single-variable parameter estimation and two-variable parameter estimation.

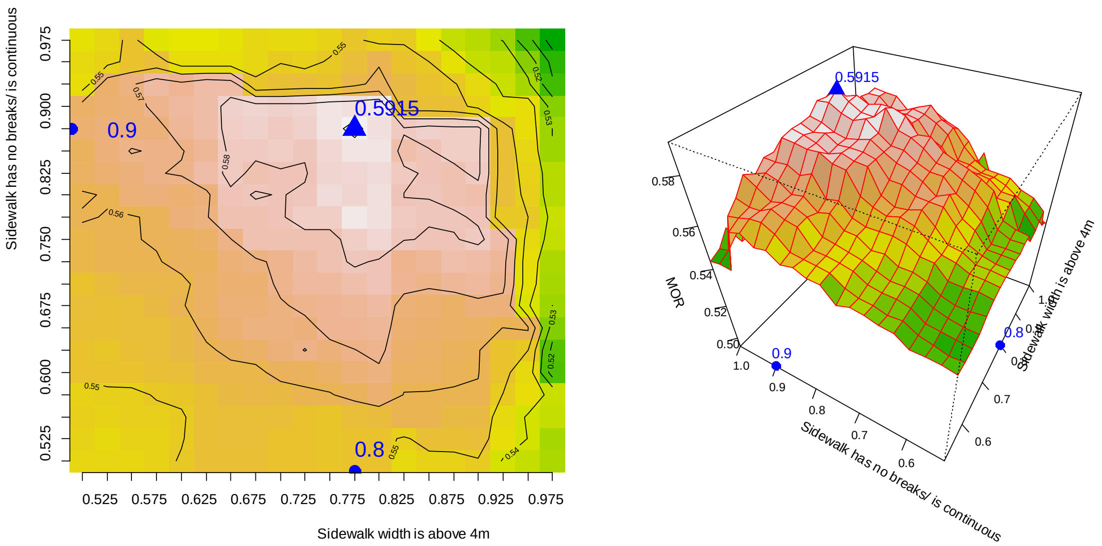


Figure 9 **Sidewalk has no breaks/is continuous** vs **Sidewalk width is above 4m**

Table 5 Result of parameter estimation (5)

Dummy Variable	Parameter [1-variable]	Parameter [2-variable]	MOR [1-variable]	MOR (Initial Overlap Ratio)
Sidewalk has no breaks/is continuous	0.61	0.9	0.539	0.5915 (0.4948)
Sidewalk width is above 4m	0.9	0.8	0.553	

Based on the results illustrated by Figure 9 and Table 5 above, the MOR of the two-variable parameter estimation for the combination of dummy variables "Sidewalk has no breaks/ is continuous" and "Sidewalk width is above 4m" is 0.0967 higher than the initial overlap ratio. Further, in comparison with the single-parameter estimation MORs, it is observed that the two-variable parameter estimation process yielded a significantly higher MOR. Thus, the combination of the abovementioned variables may highly influence route choice of non-motorized transport.

Furthermore, examining closely the differences in parameter values between single-variable parameter estimation and two-variable parameter estimation for the abovementioned variables, only the influence of the variable "Sidewalk width is above 4m" can be confirmed. Thus, considering the relatively high value of its parameter, it can be inferred that variable "Sidewalk width is above 4m" has little impact on route choice.

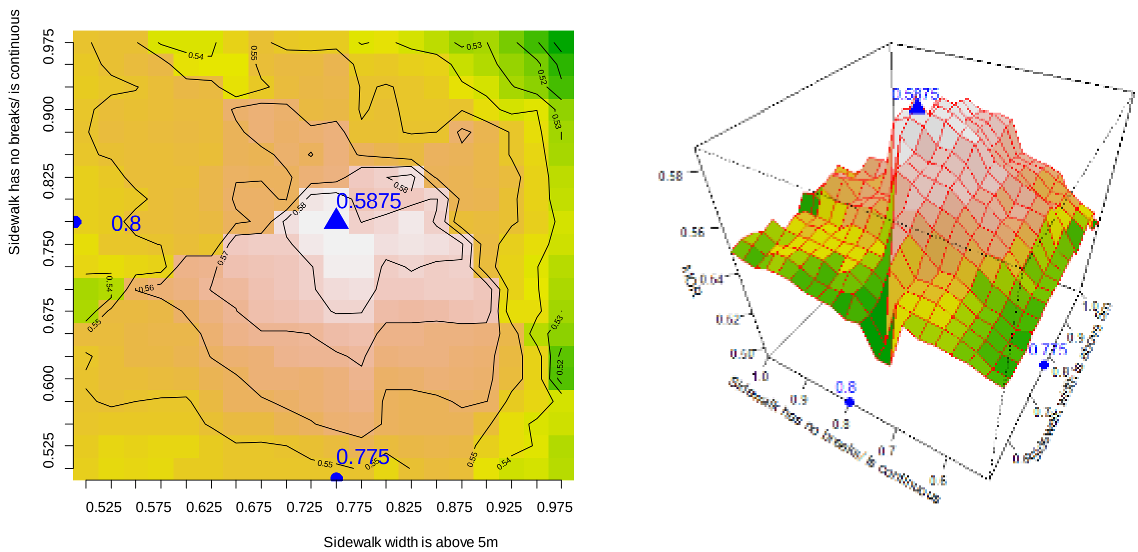


Figure 10 **Sidewalk has no breaks/is continuous** x **Sidewalk width is above 5m**

Table 6 Result of parameter estimation (7)

Dummy Variable	Parameter [1-variable]	Parameter [2-variable]	MOR [1-variable]	MOR (Initial Overlap Ratio)
Sidewalk has no breaks/is continuous	0.61	0.8	0.539	0.5875 (0.4948)
Sidewalk width is above 5m	0.81	0.775	0.551	

Based on Figure 10 and Table 6 above, the MOR of the two-variable parameter estimation for the combination of dummy variables "Sidewalk has no breaks/is continuous" and "Sidewalk width is above 5m" is 0.0927 higher than the initial overlap ratio. Likewise, in comparison with the single-parameter estimation MORs, it is observed that the two-variable parameter estimation process yielded a significantly higher MOR. Thus, the combination of the abovementioned variables may highly influence route choice of non-motorized transport.

Moreover, examining the changes in the parameter values between single-variable parameter estimation and two-variable parameter estimation, only the decrease in parameter value of the variable "Sidewalk width is above 5m" can be confirmed. Thus, considering the relatively low value of its parameter, the influence to route choice of the variable "Sidewalk width is above 5m" is considered to be large.

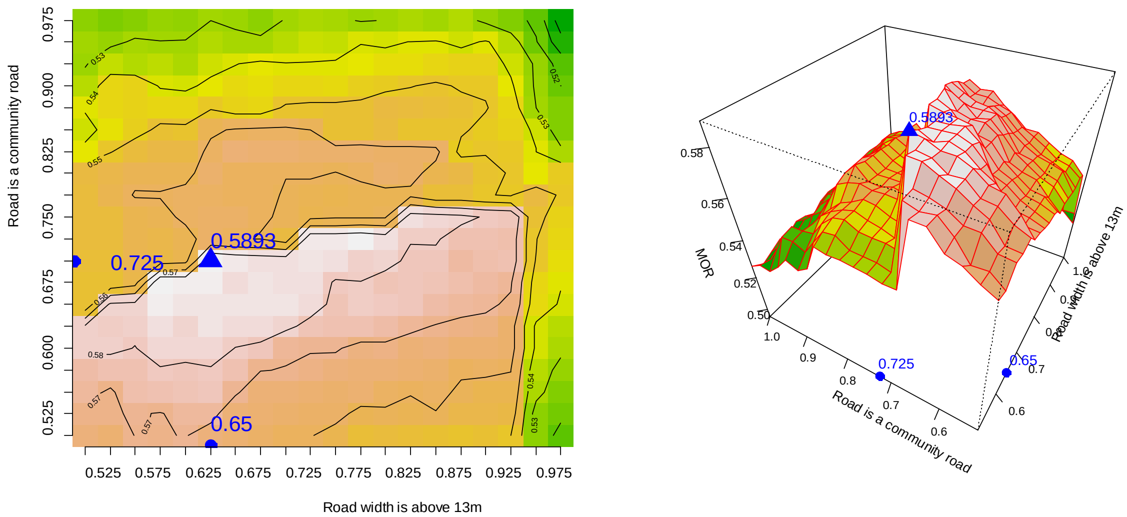


Figure 11 **Road is a community road** x **Road width is above 13m**

Table 7 Result of parameter estimation (4)

Dummy Variable	Parameter [1-variable]	Parameter [2-variable]	MOR [1-variable]	MOR (Initial Overlap Ratio)
Road is a community road	0.79	0.725	0.549	0.5893 (0.4948)
Road width is above 13m	0.81	0.65	0.533	

Examining Figure 11 and Table 7 above, the MOR of the two-variable parameter estimation for the combination of dummy variables "Road is a community road" and "Road width is above 13m" is 0.0945 higher than the initial overlap ratio. Further, since it is observed that the MOR from the two-variable parameter estimation is higher than the MOR of the single-variable parameter estimation, and that parameter values decreased in the two-variable parameter estimation relative to the single-variable parameter estimation, it may be inferred that the combination of the abovementioned variables has a high influence on route choice of non-motorized transport.

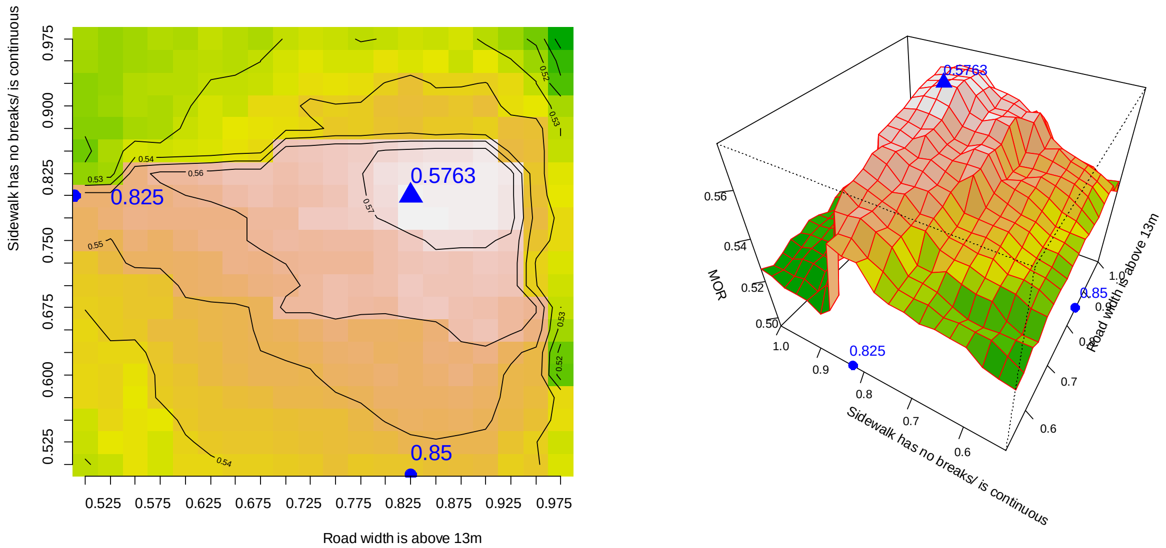


Figure 12 **Sidewalk has no breaks/is continuous** x **Road width is above 13m**

Table 8 Result of parameter estimation (3)

Dummy Variable	Parameter [1-variable]	Parameter [2-variable]	MOR [1-variable]	MOR (Initial Overlap Ratio)
Sidewalk has no breaks/is continuous	0.61	0.825	0.539	0.5763 (0.4948)
Road width is above 13m	0.81	0.85	0.533	

Based on the results illustrated by Figure 12 and Table 8, the MOR of the two-variable parameter estimation for the combination of dummy variables “Sidewalk has no breaks/is continuous” and “Road width is above 13m” is 0.0815 higher than the initial overlap ratio.

Furthermore, comparing the MOR of the abovementioned parameter estimation to the MORs of the parameter estimation of dummy variable combinations (1) and (2) (i.e., “Road width is above 13m” and “Sidewalk width is above 4m”; and “Road width is above 13m” and Sidewalk width is above 5m”, respectively), which have MORs equal to 0.5603 and 0.5607, respectively (results not presented here for practicality), it is presumed that a variable combination with variable “Sidewalk has no breaks/is continuous” increases the influence on route choice.

On the other hand, examining the results of parameter estimation, the two-variable parameter estimation yielded a higher parameter value than the single-variable parameter estimation. Further, it can be inferred that, compared to variable “Road width is above 13m”, the influence to route choice of the variable “Sidewalk has no break/is continuous” is smaller.

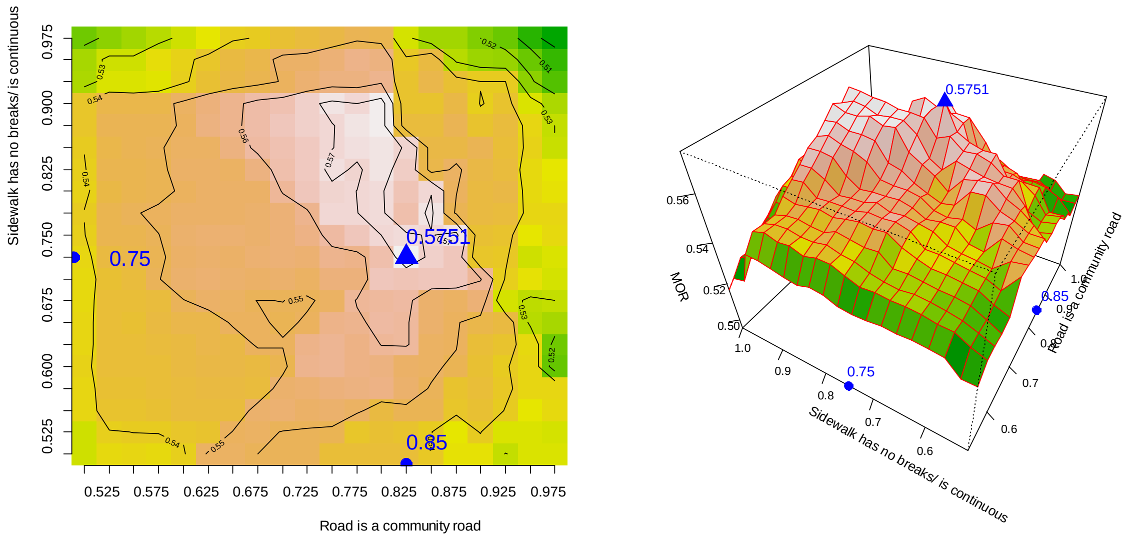


Figure 13 **Sidewalk has no breaks/is continuous** x **Road is a community road**

Table 9 Result of parameter estimation (9)

Dummy Variable	Parameter [1-variable]	Parameter [2-variable]	MOR [1-variable]	MOR (Initial Overlap Ratio)
Sidewalk has no breaks/is continuous	0.61	0.75	0.539	0.5751 (0.4948)
Road is a community road	0.79	0.85	0.549	

Based on the results illustrated by Figure 13 and Table 9, the MOR of the two-variable parameter estimation for the combination of dummy variables “Sidewalk has no breaks/is continuous” and “Road is a community road” is 0.0803 higher than the initial overlap ratio. Further, as the MOR of the two-variable parameter estimation is larger than MOR of the single-variable parameter estimation, the above combination of variable is considered to have a high influence on route choice.

Furthermore, examining the differences in parameter values between single-variable parameter estimation and two-variable parameter estimation for the abovementioned variables, only the influence of the variable “Road is a community road” can be confirmed. Thus, considering the relatively high value of the parameter of the variable “Road is a community road”, it can be inferred that the variable has significant influence on route choice.

4. SIMULATION USING THE ROUTE CHOICE MODEL FOR NON-MOTORIZED TRANSPORT

The parameter estimation process provided an understanding of the influence of certain combination of road characteristic variables to the route choice behaviour of non-motorized transport. Based on the estimated parameters, the travel demand of non-motorized transport can now be forecasted using the established model in the previous sections. Thus, a simulation case will be conducted in the succeeding subsections to demonstrate formulated model and understand the effect to route choice behaviour of a certain infrastructure development/improvement on roads.

4.1. The Case of Shizuoka City

Figure 14 to Figure 17 illustrates the non-motorized traffic in the study area based on the route choice survey data.

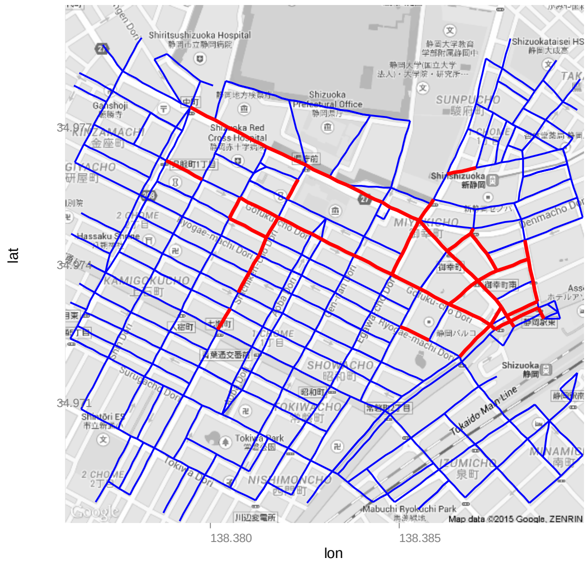


Figure 14 Traffic is greater than 100

Figure 15 Traffic is greater than 200

Figure 16 Traffic is greater than 300

Figure 17 Traffic is greater than 400

Examining the figures above, it is observed that non-motorized traffic mostly traverse three (3) roads namely, Gofuku-cho Street, Miyuki Street, and Shichigen-cho Street (Figure 18). Comparing this to the road characteristics illustrated in Figure 2 to Figure 6 in Section 2, it is surmised that non-motorized traffic choose roads with sidewalks that have no breaks/is continuous or roads that is a community road. Picture 1 to Picture 3 are images of Gofuku-cho Street, Miyuki Street, and Shichigen-cho Street, respectively.

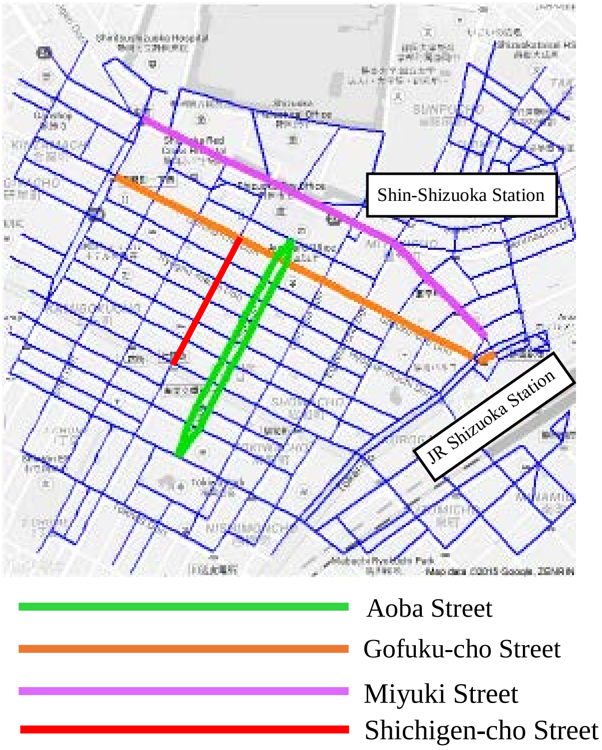


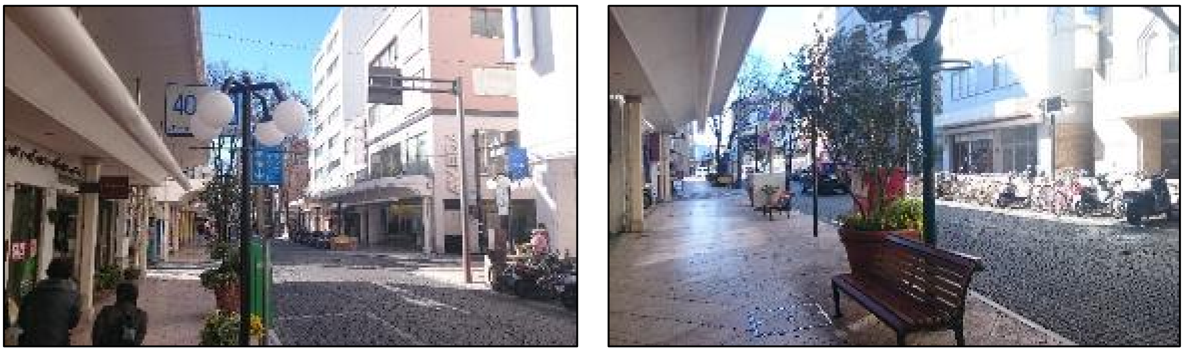
Figure 18 Streets of interest in Shizuoka City

Picture 1 Gofuku-cho Street

Gofuku-cho Street is a community road. As shown in Picture 1, Gofuku-cho Street exhibits chicane like road characteristics for slowing down vehicles, and also has wide sidewalks to allow ease of travel for pedestrians. It is also observed that there are several structures mainly for pedestrian use such as benches for resting, and that almost the entire street is filled with commercial establishments (e.g., coffee shops, clothing stores, specialty shops, etc.). This may explain why Gofuku-cho Street has a high traffic volume of non-motorized transport as illustrated in Figure 17.

Picture 2 Miyuki Street

On the other hand, Miyuki Street is one of the major thoroughfares of Shizuoka City with 2-3 lanes in both directions. Both sides of Miyuki Street are mainly office buildings. Notably, the Shizuoka Prefecture Government Office is also located in Miyuki Street as can be seen in the upper-left side of the image on the right in Picture 2 above. Sidewalks along Miyuki Street are narrow and does not have any barriers from vehicular traffic on majority of the length of the street.



Picture 3 Shichigen-cho Street

Though not a community road, Shichigen-cho Street is also notable for having a relatively high non-motorized traffic among the rest of the roads in Shizuoka City. Observing the immediate environment Shichigen-cho Street, there is an abundance of bicycle parking spaces as well as pedestrian structures such as benches and resting areas. Further, the street has wide sidewalks and is filled with commercial establishments similar to Gofuku-cho Street.

According to a Shizuoka City plan, a network of community roads is proposed to be completed as shown in Figure 19. Thus, cross-examining the plan with the non-motorized traffic illustrated above, it is observed that Aoba Street does not have sufficient traffic relative to the rest of the streets.

Figure 19 Shizuoka City plan

Picture 4 Aoba Street

Picture 4 shows the structural difference of Aoba Street from the abovementioned streets. Aoba Street consist of two (2) opposite directions one-way roads with sidewalks on one side with a wide mainly pedestrian walk in the middle of the two (2) one-way roads. Given such characteristics Aoba Street still has low non-motorize traffic. Unlike Gofuku-cho Street and Shichigen-cho Street, Aoba Street is not filled with commercial establishments or restaurants along its sidewalks.

Thus, for the simulation case of Shizuoka City, the estimated parameters from the combination of variables “Sidewalk has no breaks/is continuous” and “Road is a community road” will be utilized. Though this combination did not yield the highest MOR during the parameter estimation process, it is sufficiently high to be considered for route choice modelling. Furthermore, based on the comparison between roads traversed by non-motorized traffic and their corresponding road characteristics, it is apparent that variables “Sidewalk has no breaks/is continuous” and “Road is a community road” has influence on route choice behaviour. Finally, included in the simulation is a road infrastructure improvement by transforming Aoba Street into a community road as it is also in the Shizuoka City plan to increase non-motorized traffic in Aoba Street.

4.2. Results of Simulation

Figure 20 and Figure 21 below illustrates the results of the simulation utilizing the estimated parameters of variables "Sidewalk has no breaks/is continuous" and "Road is a community road" from the two-parameter estimation process as presented in Table 9 in Section 3.

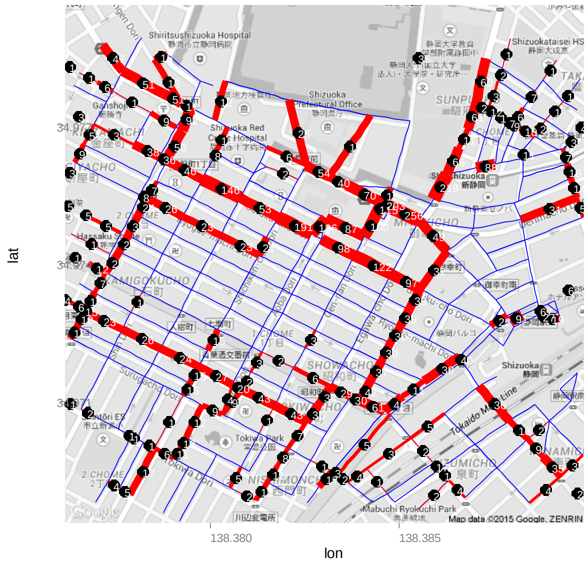


Figure 20 Increase in non-motorized traffic
Case 1: No improvement to Aoba Street

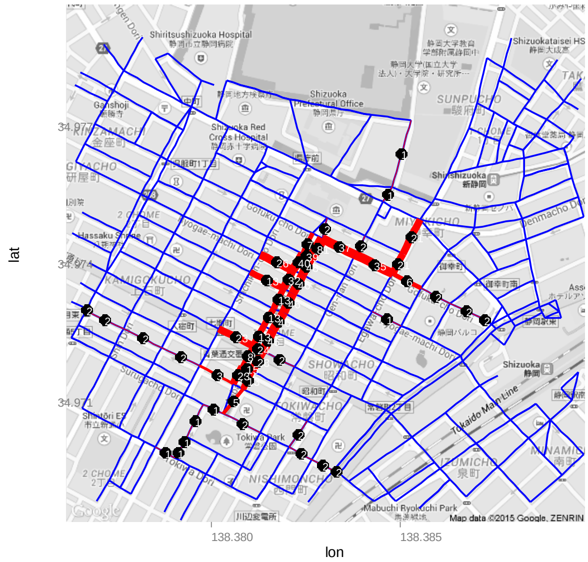


Figure 21 Increase in non-motorized traffic
Case 2: Aoba Street transformed into a community road

Examining the simulation of Case 1 (Figure 20), where no improvement to Aoba Street was done, and cross-examining it with the Figure 5 (Sidewalk has no breaks/is continuous) and Figure 6 (Road is a community road) from Section 1, it is apparent that there is an increase in non-motorized traffic on links that fulfil either of the conditions of "Sidewalk has no breaks/is continuous" or "Road is a community road." Thus, confirming the influence of variables "Sidewalk has no breaks/is continuous" or "Road is a community road" on the cognitive minimum/shortest path of a walker/bicycle user. However, it is also observed that Aoba Street didn't have any increase in non-motorized traffic, as expected, as it is not a community road.

As it is the aim of this paper to demonstrate the forecasting capabilities of the model and its ability to understand the impact of an infrastructure development to non-motorized transport behaviour, and further to complete the community road network of Shizuoka as planned, an improvement was included in the simulation through the transformation of Aoba Street into a community road (Case 2). Based on the results of Case 2 simulation (Figure 21), there is an increase in non-motorized traffic in Aoba Street when it is transformed into a community road.

The result of the simulation demonstrates and confirms the influence of variables "Sidewalk has no breaks/is continuous" or "Road is a community road" to the cognitive minimum/shortest path of non-motorized transport and allows the ability to understand and forecast an improvement or infrastructure development's impact to route choice behaviour. However, it should be noted that though it seems that based on the result of the estimation above that community roads (and its corresponding road characteristics) tend to be chosen by non-motorized transport, until similar studies are conducted on different study areas or a wider study area involving other cities, the above result may be a special case and thus it cannot be concluded that community roads have a definite influence on non-motorized transport route choice behaviour.

5. CONCLUSIONS

This study presented a heuristic method utilizing the Maximum Overlapping Ratio Model (MOR) to model non-motorize transport route choice behaviour. By estimating parameters and maximizing the MOR of combination of variables representing road characteristics, the influence to route choice of non-motorized transport, specifically the influence to cognitive/perceived distance of a path, was established.

The study revealed that road characteristics influence route choice behaviour of non-motorized transport and that the shortest path from origin to destination may not necessarily be the path taken by non-motorized travellers suggesting that it may be advantageous to consider road characteristics that highly influence route choice.

Thus, through the route choice model, it was shown that certain road characteristics impact route choice of non-motorized transport; and by considering road characteristics that highly influence route choice and utilizing the model, the impact on route choice of certain road infrastructure improvements may be determined especially in forecasting demand.

Finally, by being able to understand the variables that influence route choice of non-motorized transport, it is possible to influence the route choice behaviour of walkers and cyclers depending on the requirements/necessities of a certain plan by an authority (e.g., increasing traffic, decreasing traffic, etc.). In this regard, before implementing road infrastructure improvements, the developed route choice model may be used as an evaluating tool to assess the impact of possible improvements or developments to route choice behaviour of non-motorized transport provided that appropriate RP survey data are collected which must include route data of the respondents.

6. RECOMMENDATIONS FOR FURTHER STUDIES

The heuristic nature of the estimation process allowed for flexibility in the variables for parameter estimation. For further studies, it may of interest to consider as variables the land-use classification of areas/structure adjacent to links of paths traversed to understand the influence of land-use to route choice behaviour of non-motorized transport. It is because that it may not only be road characteristics that actually influence route choice but also the nature of establishments along the path that non-motorized travellers take.

It was previously mentioned in the beginning that the presence of traffic signals were not included in the road network data used for the study. This may not have significant impacts on this study, however it may have significant effects in other study areas as related research have found traffic signals to have influence on bicycle route choice (Broach *et al.*, 2012; Sener *et al.*, 2009). Thus, the presence of traffic signals may be included in future studies to strengthen the model and make sure that the influence of traffic signals be accounted for (may it be significant or not) during the model estimation.

Further, the model may also be expanded to other transport systems or modes that primarily utilize roads as routes. Hyodo *et al.* (2013) utilized the MOR model for modelling maritime container trailer route-choice behaviour in Japan which also considered road characteristics. As Japan is a developed country, it may also be of interest to apply the model to developing countries' land based logistics systems. However, care should be taken with regard to possible variables that influence route choice behaviour as it is likely that there are more factors to be considered with respect to developing countries that are not usually present in developed countries (e.g., road structural conditions, commuting behaviour of pedestrians, disregard of traffic rules of motorists, etc.)

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