INFLUENCE OF LEVEL-OF-SERVICE OF SIDEWALKS AND CROSSWALKS ON PEDESTRIAN ROUTE CHOICE BEHAVIOR*

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1. Introduction

Investigating pedestrian route choice behavior in urban areas may help us to clarify the benefits of improving pedestrian level-of-service (LOS) at walkways. The results would also be useful to know what type of facilities and infrastructure programs should be improved to promote walking. The comparative analysis of the actual versus alternative routes shall point out whether pedestrians choose roadways that are more closely associated with LOS, shortest distance, or some combination of these factors. Existing route choice models are generally based on the hypothesis that pedestrians minimize their travel time or travel distance. Some researchers have proposed qualitative measures for different factors affect the walking behavior of pedestrians, such as the distance to their destination, the personal characteristics of pedestrians, trip purpose, route familiarity, recreational points of interest, and environmental conditions. One study addressed bottlenecks and the presence of obstructions on walkways[1]. Models were developed on the basis of a quantification theory by considering sidewalk type, the presence of pedestrian facilities, the number of attractions, and surface quality as explanatory variables[2), 3)]. A review of previous research papers in this area indicated that the following features influence the route choice behavior of pedestrians; distance between origin and destination, walkway width, surface characteristics (paved versus unpaved), recreational points of interest, available facilities, conflicts with motor traffic, pedestrians' socioeconomic characteristics such as age, gender, income, personality, habits and preference, pedestrians' walking experience and familiarity with the transportation network, pedestrians' trip characteristics including trip purpose, time and location, flexibility in arrival time, availability of possible alternative routes between an origin and destination pair, and traffic conditions.

In general, if there are several alternative routes to reach a particular destination people choose the shortest route to reach their destination. However, the street network in Sapporo is designed in grid pattern and selecting whatever routes are almost same in distance for a given origin and destination. Therefore it has been thought that pedestrians select their routes according to the LOS of walkways by minimizing the difficulty of the walking or maximizing the facility continuity. Based on this judgment, a hypothesis was established that not only the travel distance but also the road LOS has an effect on route choice behavior of pedestrians. Hence, a specific research was designed in this study, to examine the influence of LOS on pedestrian route choice behavior. Using revealed preference survey data, a comparative analysis between actual routes and calculated alternative routes was performed by ArcGIS Network Analyst. Based on the results, multinomial logit model was developed to express quantitatively the route choice behaviors of pedestrians.

2. Methodology

(1) Revealed Preference Survey

Pedestrian travel characteristics in Sapporo city were surveyed by using revealed preference survey approach to find out the routes chosen by pedestrians. How pedestrians choose their routes was investigated by asking them to draw their paths on maps. In the revealed preference survey, the first section of the questionnaire had focused on the pedestrian trip with questions about the trip origin and destination. In the questionnaire, each subject had been asked to indicate his or her origin and destination on the map. If the origin and final destination is outside of the map area, then the subjects were requested to indicate his or her 'internal trip origin' and 'intermediate destination' (i.e. subway station, bus stop, parking lot) on the map. Questionnaire asked each subject to trace the

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'most frequently traveled route' on which they usually walk to work or school. They have been asked to draw their routes for both trip directions (Home-to-work and Work-to-home) and non-commuting trips. In the second section of the questionnaire, subjects were asked to give individual characteristics which gives general and background socioeconomic information, such as age, gender and income. In total, 1,500 mail-back surveys were distributed during on-street surveys at selected survey locations. To capture the weekday peak period and the weekend peak period, surveys were distributed during weekday and weekend morning, afternoon, and evening peak travel periods. 346 questionnaires were returned with an average response rate of 23%.

(2) Collecting Characteristics of Sidewalks and Crosswalks

This process starts with a detailed survey (a block-by-block survey) of site, examining the geometric and operational aspects of the sidewalks and crosswalks. All characteristics relating to each factor affecting LOS were collected for each sidewalk and crosswalk in an area within and surrounding of Hokkaido University. Figure 1 shows the surveyed area where almost all the streets have sidewalks on both sides and crosswalks at intersections. In total, 217 sidewalk segments and 210 crosswalks were surveyed.

(3) Creating Network Dataset using GIS

Recent developments in Geographic Information Systems (GIS) provide network-based spatial analysis to manage the large amount of spatial related data and to obtain route choice information from the raw data. The new ArcGIS Network Analyst is a recently developed powerful extension of the ArcGIS 9.1 platform. ArcGIS Network Analyst provides travel-time analysis, point-to-point routing, route directions, shortest path, optimum route, closest facility and origin-destination analysis. Using ArcGIS Network Analyst, we can create network datasets and perform analysis on geodatabase data and shapefiles. A GIS based network data was used in this research to (a) store the characteristics of sidewalks and crosswalks; (b) identify the shortest-path routes, and optimal LOS routes between each origin-destination pair; and (c) compare them to actual routes between the corresponding origin-destination pairs. Shape-file based network dataset was created on the ArcGIS 9.1 platform. The characteristics of sidewalks and crosswalks were stored in this GIS network dataset. GIS network data includes data about the road network itself, and LOS data of sidewalks, and crosswalks. Sidewalk characteristics include width, obstructions along sidewalk, pedestrian flow rate, and number of bicycle events. Crosswalk characteristics include space at corners, crossing facilities, turning vehicles, and delay at signals. After determining the each attribute level of a specified sidewalk or crosswalk by doing field survey, utility values were assigned to each level using the results of the conjoint analysis[4)]. Then utilities for each attribute level are used to calculate the total utility for a particular sidewalk or crosswalk. The total utility of the combination was changed to a level of service designation. Each link element is assigned to a LOS as shown in Figure 2.

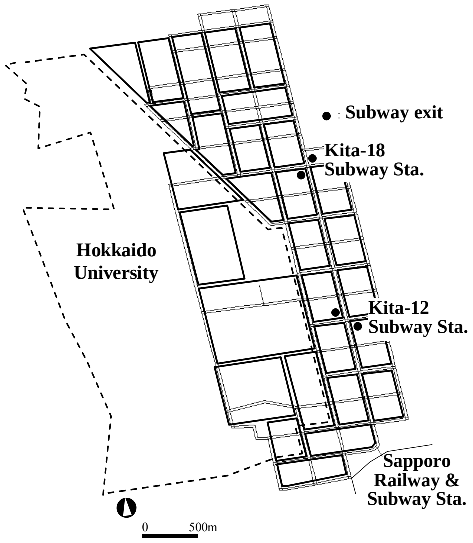

Figure 1: Study area

Figure 2: LOS Score distribution of sidewalks & crosswalks

(4) Importing Actual Route

The actual route of each respondent was collected from the collected maps of revealed preference surveys and imported into GIS network data. The actual route entered into GIS is consisting of series of links and nodes. The route entry part into GIS route analysis was time consuming. Origins and destinations were located on the network by using the Create Network Location tool.

3. Alternative Routes Using GIS Network Analysis

Two network attributes called (a) 'Shortest Path', and (b) 'Pedestrian LOS' were established. These two attributes are the network properties that function as impedances over the network. The 'Pedestrian LOS' attribute in the network represents the pedestrian LOS on the network. In this case it has two components because a pedestrian can utilize the crosswalk in addition to walking along the sidewalk. The following two alternative routes were created using ArcGIS Network Analyst

a) Shortest path between the same origin and destination of the actual route

b) Optimized LOS path between the same origin and destination of the actual route

The optimized LOS path between the same origin and destination was calculated based on the length of each link. As shown in the equation below, length of each link and its LOS control the network navigation.

$$\text{Optimized LOS} = \frac{\sum_{i=1}^{n} U_i X_i}{\sum_{i=1}^{n} X_i} \qquad (1)$$

Where U_i is the utility based LOS of i th link

X_i is the length of the i th link

(1) The distance of Actual and Alternative Routes

The mean distance of the actual route is 0.885 kilometers. The distance distribution of actual and alternative routes is shown in Figure 3. The null hypothesis that the distances of actual routes have the same distribution compared to the distances of shortest and LOS routes was rejected at the 0.1 and 0.05 significance level respectively by the chi-square test.

(2) LOS of Actual and Alternative Routes

The LOS value of actual route and alternative routes were compared. Computed value of actual route and alternative routes are shown in Figure 4 and Figure 5. According to Figure 4 and Figure 5, it can be noticed that LOS of the traveled route has a strong influence on route choice behavior. It indicates that pedestrians do not always choose shortest routes and they prefer to choose routes which are in better conditions.

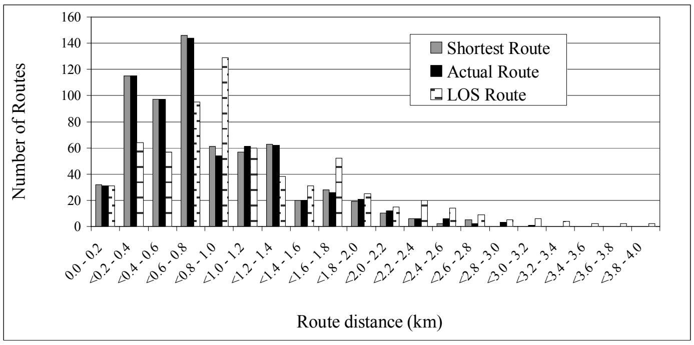

Figure 3: Total distance of actual and alternative routes vs number of routes

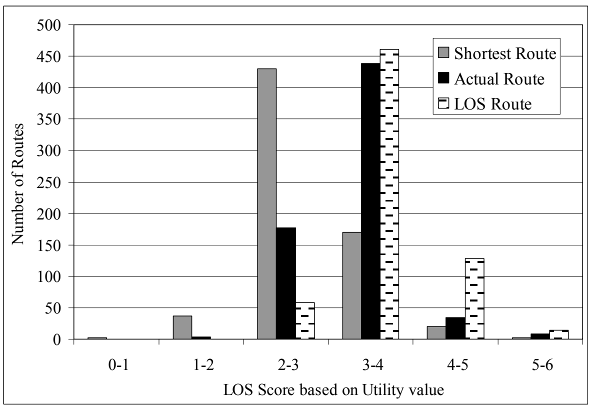

Figure 4: LOS of actual and alternative routes

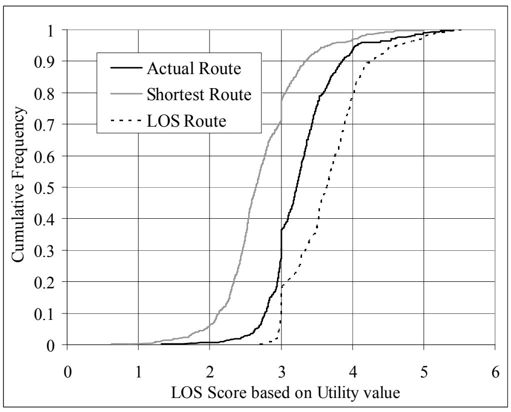

Figure 5: LOS of actual and alternative routes (Cum. Freq.)

4. Modeling Pedestrian Route Choice Behavior

The multinomial logit model leads to some of its most valuable properties and has made it the most widely used method for discrete choice analysis[5]. Hence, we have adapted multinomial logit model as a model describing pedestrian route choice behavior. The multinomial logit (MNL) is expressed as,

$$P = \frac{\exp(\alpha + \beta[Distance\ of\ the\ Route]_j + \gamma[LOS\ of\ the\ Route]_j}{\sum_J \exp(\alpha + \beta[Distance\ of\ the\ Route]_j + \gamma[LOS\ of\ the\ Route]_j} \quad (2)$$

Where, α, β, and γ are the parameters to be determined. P is the probability of an individual chose alternative j; P = 1 for the actual route; P = 0 for alternative route (This study considers the shortest distance routes and optimized LOS routes as the alternative routes). The data corresponding to input variables were imported into the LIMDEP statistical software for modeling analysis. The calculated parameter values are shown in Table 1. The absolute t-values of all parameters are >1.96, and all have a 5% level of significance. The positive sign of the parameter value corresponding to 'route LOS' indicates that the probability of a route being selected increases with the increasing value of route LOS.

Table 1: Results of Pedestrian Route Choice Model

Parameter	Parameter Value	t-value	Significance level
Constant (α)	-2.163	-5.711	0.000
Distance (β)	-1.849	-14.648	0.000
Utility based LOS Score (γ)	1.303	3.437	0.000
Log likelihood function	= -772.7629	Restricted log likelihood	= -946.1303
Chi-squared	= 346.7348	Degrees of freedom	= 3
Number of observations	= 1366	Significance level	= 0.000

5. Summary and Conclusions

This work focused on examining the influence of LOS on pedestrian route choice behavior. We have examined the pedestrian route choice behavior using the applicable range of ArcGIS Network Analyst. A multinomial logit model that takes into account of pedestrian LOS has been proposed and estimated. The results suggest that pedestrians choose roadways that are more closely associated with the combination of both features; LOS and travel distance. The positive sign of parameter corresponding to LOS can be explained as pedestrians' preference for LOS during their route choice. The probability of a route being selected increases as the LOS of that route increase. As expected, the length of the route has a negative impact on the probability of being selected. The results of this study can be used to assess quantitatively the benefits of improving pedestrian LOS at walkways. The results would also be useful to know type of pedestrian facilities that should be improved to promote walking.

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