A Study on Evaluation of Pedestrian Level of Service along Sidewalks and at Intersections Using Conjoint Analysis

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INTRODUCTION

One of the most common approaches used to assess transportation facilities is the concept of LOS [1]. It is generally recognized that LOS value enables us to understand and qualify the street design elements that are conducive to the needs of pedestrians. Review of literature reveals that much more researches were carried out on LOS of motorized transportation compared to that of pedestrian LOS. Proposed LOS in the 2000 Highway Capacity Manual [1] for pedestrians is mainly based on the capacity and space requirements (flow-speed-density relationships). Although recent researches on pedestrian LOS indicate that there are also factors that affect pedestrians LOS [2], none of the existing methodologies covers the full range of pedestrian LOS. Transportation planners and researchers have not yet come to a conclusion on which features of a roadway environment have statistically reliable significance to pedestrians. Therefore a method is needed to determine how compatible a roadway is for allowing efficient operation of pedestrians. The purpose of this study is to propose a method to determine the LOS of a pedestrian path with the aid of conjoint technique. The method provides not only LOS of pedestrians but also determining which factors contribute to low and high LOS. As most of the existing methodologies of pedestrian LOS look into account only the sidewalk conditions (i.e., excluding crosswalks), in this study the conditions of both sidewalk and crosswalk are considered in the computation of LOS.

METHODS

Study Area

In the city of Sapporo, the area within and surrounding of Hokkaido University is occupied by a considerable number of pedestrians because of sidewalks on both sides of the roads and transit points such as Sapporo station, Kita-12 and Kita -18 subway stations. Figure 1 shows the selected area for this study, which covers both outside and inside of the campus.

Figure 1 Range of the study area

Conjoint Analysis

Conjoint technique is an extremely powerful way of capturing what users really value a service or product. It has been used this study to understand how pedestrians value the features of services by determining their trade-offs between different levels. Conjoint analysis estimates an individual's "value system", which specifies how much a user puts on each level of the attributes [3]. Therefore using conjoint analysis we can determine what attributes are important or unimportant to the pedestrians as well as the utilities for each attribute level.

Classification of Attributes and Levels

We established 8 attributes and 3 levels for each attribute by referring to LOS standards. Two sets of attributes and levels shown in Table 1 and Table 2 were used to create profile cards. Visual representation of these two sets is illustrated in Figure 2 and Figure 3. Separation of the

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Table 1 Attributes and levels of sidewalk

Level	Attributes			
	Width & Separation	Obstructions	Flow rate (ped/min/m)	Bicycle events
Level 1	More than 3m wide & excellent separation	No obstructions	Less than 24	≤60 events/h
Level 2	From 1.5 to 3m & reasonable separation	From 1 to 5 obstructions per 100m.	From 24 to 49	From 61 to 144 events/h
Level 3	Less than 1.5m wide & no separation	More than 5 obstructions per 100m	More than 49	>144 events/h

Table 2 Attributes and levels of intersection

Level	Attributes			
	Space at Corner	Crossing Facilities	Turning Vehicles	Delay
Level 1	Enough waiting & circulation space	Excellent facilities	No turning vehicle	Less than 10 seconds
Level 2	Only waiting space is reasonable	Standard is provided but more needed	Left turning vehicles	From 10 to 40 seconds
Level 3	Both spaces are not enough	Crossing facilities are lacking	Left & right turning vehicles	More than 40 seconds

pedestrians from motorized traffic is combined with the width of sidewalk because separation translates originally into the existence of a sidewalk [4]. Several types of walkway obstructions tend to make pedestrians shy away. The obstructions may be permanent (e.g. improper utility poles and boxes, store displays, quality of the surface, etc.) or temporary (e.g. garbage station, parked bicycles, etc.). The measure of pedestrian flow is the freedom to choose the desired speeds and walk freely without congestion. Bicycle events indicate the frequency that the average pedestrian is overtaken by cyclists. There are two types of pedestrian area requirements at street corners: circulation area - necessary for moving pedestrians; and hold area - necessary to accommodate waiting pedestrians. Therefore area size includes both hold area and circulation area. Crossing facilities include high visibility ladder style cross markings, separate path for bicycles, well-designed curb ramps, detectable pathfinder tiles for people who are visually impaired, and raised median protection/ refuge islands (if the street is too wide to cross in a single signal phase). The potential for pedestrian-vehicle conflict is represented by the turning vehicles. The total time spent by pedestrians waiting to cross the street is called delay.

Production of Profiles

A minimum number of cards called profiles has been generated by SPSS software. SPSS conjoint uses fractional factorial designs, which present an appropriate fraction of possible alternatives. The ORTHOPLAN procedure generates orthogonal fractional factorial plans. In total 11 profiles were generated including 2 holdout profile cards.

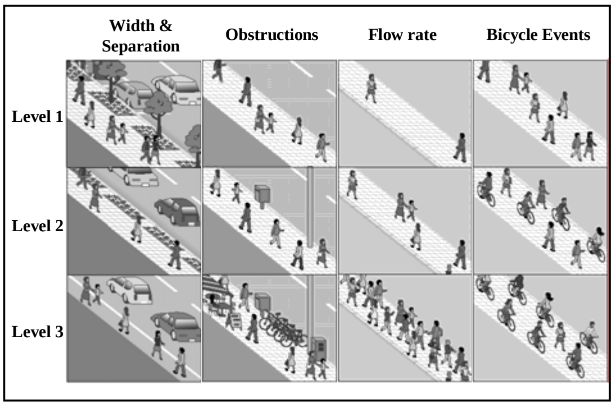

Figure 2 Attributes and levels of sidewalk

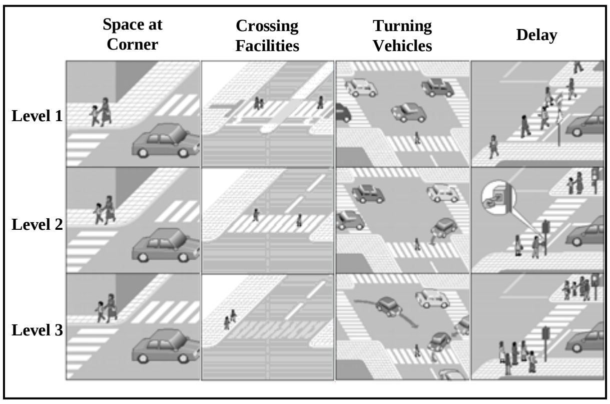

Figure 3 Attributes and levels of intersection

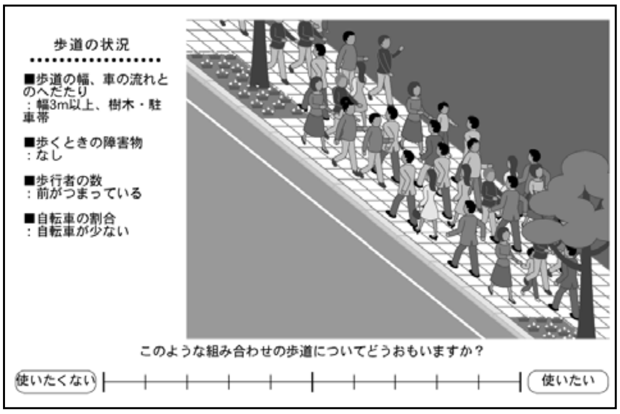

Figure 4 One of the profiles used for survey (sidewalk)

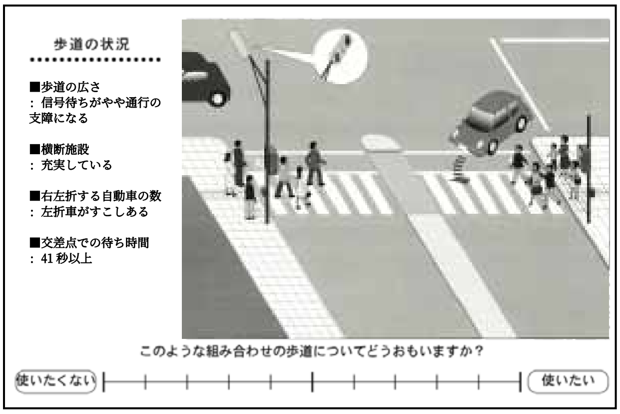

Figure 5 One of the profiles used for survey (crosswalk)

For easy understanding of the profiles, drawings were designed using vector graphic software called “Illustrator”. Some of the profiles used for survey are shown in Figure 4 and Figure 5. Respondents were asked to express their

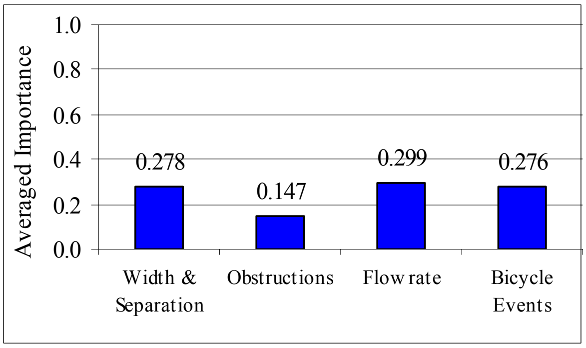

Figure 6 Averaged importance of each attribute of sidewalk

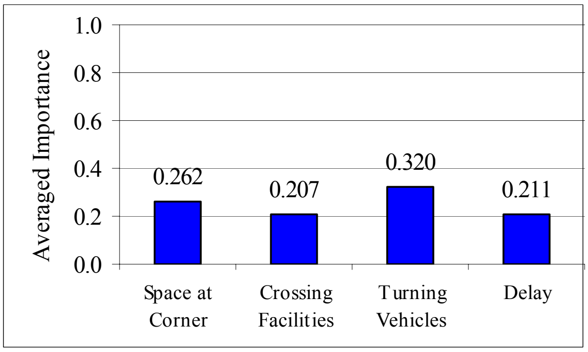

Figure 7 Averaged importance of each attribute of intersection

view of the sidewalks shown in the profiles concerning "I do not like to use" or "I would like to use", using a scale shown at the bottom of the profile.

Procedure

Questionnaire survey was conducted between 21 to 24 November 2002. One thousand questionnaires were distributed by visiting houses in the areas around Hokkaido University. Respondents were requested to return the answered questionnaires by mail. The total number of recovered questionnaires was 531.

RESULTS

Averaged Importance and Utility Values

Figure 6 indicates an averaged importance of each attribute of sidewalk. The most significant factor is flow rate of pedestrians. Width & separation and % of cyclists have almost same influence on pedestrians. Obstructions do not have much influence when compared with other attributes. Figure 7 shows averaged importance is mainly affected by turning vehicles at intersections. It is also noted that area size is the second important attribute.

Utilities are basically index numbers which measure how valuable or desirable a particular feature is to a pedestrian. Figure 8 shows the utility values of each level of sidewalk. It can be noted that level 1 and level 2 of width & separation are positive utilities. The range between utility

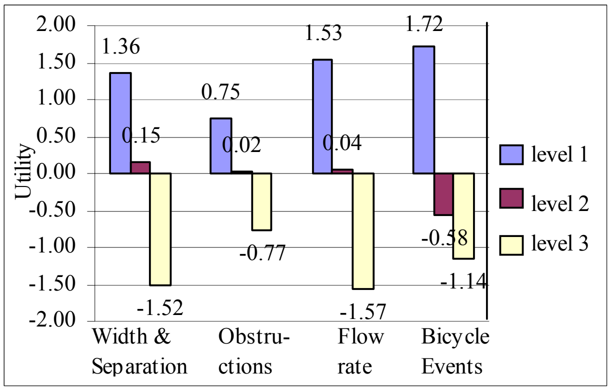

Figure 8 Utility value for each level of sidewalk

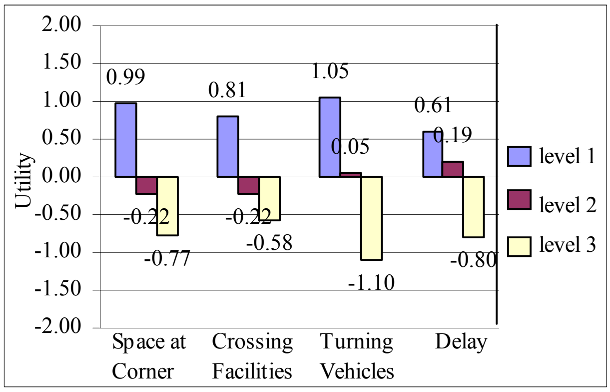

Figure 9 Utility value for each level of intersection

Table 3 Utility values of sidewalk for the age group under 20

	Width & Separation	Obstruc -tions	Flow rate	Bicycle events
Level 1	1.18	0.55	1.54	1.67
Level 2	0.29	0.21	0.05	-0.56
Level 3	-1.47	-0.76	-1.60	-1.11

Table 4 Utility values of sidewalk for the age group 30-39

	Width & Separation	Obstruc -tions	Flow rate	Bicycle events
Level 1	1.35	0.70	1.74	1.86
Level 2	0.23	0.00	-0.13	-0.56
Level 3	-1.58	-0.70	-1.61	-1.30

Table 5 Utility values of sidewalk for the age group over 60

	Width & Separation	Obstruc -tions	Flow rate	Bicycle events
Level 1	1.41	0.82	1.48	1.86
Level 2	0.05	-0.18	0.16	-0.74
Level 3	-1.46	-0.63	-1.64	-1.12

levels of flow rate is wider than other attributes. Utilities of level 2 and level 3 of % of cyclists are negative values. According to Figure 9 both Level 2 and level 3 of space at corner and crossing facilities have negative utilities. Utilities of turning vehicles have a wide range when compare to the other attributes. In case of delay, only the third utility is negative.

Segmentation Study

Individual characteristics (gender, age, occupation, mode of travel, walking time, etc) of respondents were also collected in order to group them with the same preferences into the same segment. Percentage of male (53%) and female (47%) response to this survey is approximately the same. The range of age is wider and uniformly distributed. 14% are under 20, 20% are within 20-29, 15% are 30-39, 18% are 40-49, 17% are 50-59 and 17% are over 60. Segmentation had been done for each group separately. Segmentation analysis shows similar patterns among the groups. For example, Table 3, Table 4, and Table 5 show the utility values of sidewalks for the age groups under 20, 30-39, over 60 respectively. Even though there is a slight different in utility values it can be noted that there is almost same trend with overall result. Segmentation for the case of gender is also matching with the trend of overall result. The same behaviors as utility values of sidewalk were observed in case of utility values of crosswalk. Therefore the overall result is reliable one and can be used as a common for all surveyed groups.

Analysis of Results

The result indicates that the surveyed pedestrians see greater importance between levels of flow rate than other attribute levels. The second finding is bicycles can have a negative effect on pedestrians in the shared paths. Since level 1 and level 2 of width & separation are positive utilities we may conclude that pedestrians feel unsafe only where there is no sidewalk in the roadside environment. The other point is removal of obstructions from pedestrian passageways will make only a slight change in LOS of pedestrian.

At the corners of intersections both waiting area (hold area) and the space for moving (circulation area) should be wider than the standard size because the standard level (level 2) has a negative utility. In case of crossing facilities pedestrians prefer design improvements, such as high visibility zebra style cross markings, separate path for bicycles, and well-designed curb ramps. When the number of turning vehicles increases, the result shows a corresponding decrease in the perceived safety to the pedestrian. Another interesting observation regarding intersection is that pedestrians prefer Pedestrian-Priority-Crossings and they do not accept long delays at signalized intersections.

LOS Estimation Using Utilities

By adding utility scores the total utility of a specific combination can be computed. The maximum total utility value indicates the best case, while minimum indicates the worst case. All LOS grades lie within these two extremes. The difference between the best and the worst is divided into six segments to assign a linear model for LOS. The linear model expresses an expected linear relationship among the LOS grades. Geometric and operational characteristics relating to each factor affecting LOS within the model have been collected to estimate the LOS for a particular sidewalk or crosswalk. After determination of level of each attribute to the specified place, utility values are assigned to each of them using the results of conjoint analysis. After that the total utility of the combination has been changed to a level of service designation.

CONCLUSIONS AND FURTHER RESEARCH

Eight attributes affecting pedestrian LOS have been defined and they were weighted by relative importance through conjoint analysis using the survey data. It was observed that if possible roadway planners must avoid shared use paths because pedestrians feel discomfort due to bicycle-to-pedestrian interaction. Also at the corner when there are turning vehicles, the result shows a corresponding decrease in the perceived safety to the pedestrian.

In addition to these findings, a method for the assignment of a LOS grade was developed based on identified attributes. Utilities from conjoint analysis are used to calculate the total utility for a specified sidewalk or intersection. After that the total utility is used to assign LOS. Further research of this study is validation which allows us to compare the results of our proposed method and real-world data. In order to fulfill this requirement we decided to carry out a survey with real pedestrians.

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