METHOD TO DETERMINE OVERALL LEVEL-OF-SERVICE OF PEDESTRIAN WALKWAYS BASED ON TOTAL UTILITY VALUE *

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1. Introduction

It is necessary to objectively quantify how well roadways accommodate pedestrian travel. Such a measure of walking conditions would greatly aid in roadway cross-sectional design and would help in evaluating and prioritizing the needs for sidewalk retrofit on existing roadways[1]. Estimation of pedestrian level-of-service (LOS) is the most common approach in assessing the quality of pedestrian facilities. It is generally recognized that the value of having such standards is the contribution they would make to understanding and quantifying the street design elements that are conducive to the needs of pedestrians[2]. Studies on pedestrians have found that a pedestrian in the roadside environment are subjected to a set of several factors significantly affecting his or her perception of safety, comfort, and convenience. Measurement of these factors is necessary to evaluate the pedestrian facilities. Although most of the existing methodologies identify the factors affecting pedestrian LOS, many of the factors are not directly included in the computation of LOS. Also these factors are qualitative and can not be measured easily. A method is needed to include the factors into the direct computation of LOS.

The first attempt was made by Lautso and Murole to find out the influence of environmental factors on pedestrian facilities. This research was a milestone in pedestrian LOS research, and it was further expanded by later researchers to accommodate many important factors into the computation of pedestrian LOS[3]. Sarkar proposed a qualitative method to compute pedestrian LOS based on six factors: safety, security, convenience and comfort, continuity, system coherence, and attractiveness[4]. Qualitative attributes of pedestrian environments are described, but not quantified, in Sarkar's work. Since it is a qualitative method, the measurement of each factor is not easy in reality and also most of the factors are linked with each other. Later Khisty[5] developed a quantitative method to determine the pedestrian LOS based on almost same criteria proposed by Sarker. Although Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret. A fundamental question remains as whether these scaling systems really address the pedestrian facilities, i.e. do pedestrians agree with these scaling systems. John et al.[6] also proposed a scale method for pedestrian LOS assessment. Alternatives were introduced to improve the existing conditions and the proposed model was calibrated by using 3-D visualization. Dixon proposed a pedestrian LOS evaluation criterion which involves the provision of basic facilities, conflicts, amenities, motor vehicle LOS, maintenance, and travel demand management, and multimodal provisions[7]. Landis et al.[1] proposed a mathematical model to evaluate a roadway segment. However, this model is limited with environmental factors only and does not include other factors such as flow rate of path users, space requirements, etc. The Highway Capacity Manual (HCM) 2000 provides LOS analysis for each factor affecting pedestrian facilities[8]. However, the HCM gives relatively little guidance on compiling the LOS of each factor into a measure of overall LOS. Therefore it has been recognized that the pedestrian LOS must be estimated as a function of all factors.

This study proposes a term called 'overall LOS' as an index that combines the factors and indicates an overall value for the pedestrian LOS. Using the value of overall pedestrian LOS, people can understand how well a particular street accommodates pedestrian travel. The proposed method in this study is based on the concept of total utility value, which comes from a conjoint analysis research[9]. Total utility from the conjoint analysis represents an overall value, which specifies how much value a user puts on a product or service. The maximum total utility value indicates the best case, while minimum indicates the worst case. This means that the maximum total utility is the upper limit of overall LOS and the minimum total utility is the lower limit of overall LOS. Therefore an assumption was made that there is a linear relationship between the total utility of a specified sidewalk and overall LOS of that particular sidewalk. To test this assumption, a validation process was designed and conducted in this research. Validation is defined as the process of

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determining the degree to which a model accurately represents the real-world, in terms of the intended uses of the model[10]. Validation allows us to compare the results of the proposed method and real-world data. Toward this, pedestrians were surveyed. The scores given by surveyed pedestrians were compared with the total utility values which were calculated from the field measurement data.

2. Methods

(1) Field survey

This process starts with a detailed block-by-block survey of the site, examining the geometric and operational aspects of the sidewalks. All characteristics of factors affecting LOS were collected for each sidewalk at Hokkaido University and its peripheries. Figure 1 shows the range of the area undergone thorough field measurement. In the surveyed area almost all the streets have sidewalks on both sides. In total, 217 sidewalk segments were surveyed. In the field measurement process, we were able to introduce measurement methods for each factor considered in this study. Some of these factors are not easy to define and measure. But many of the factors are clearly defined in HCM 2000. Therefore HCM was used to define and measure those factors. In addition to HCM, past research papers were referred to define other factors not defined in HCM. Three levels were assigned to each factor with the help of HCM 2000 and other research papers. HCM 2000 uses six levels from A to F. However this study confines itself to three levels. Level 1 is defined as high LOS and includes LOS A & B from HCM 2000. Level 2 (medium LOS) and level 3 (low LOS) were respectively defined as combination of LOS C & D, and LOS E & F. Field measurement of each factor and its levels are detailed below by referring the research works done in the past.

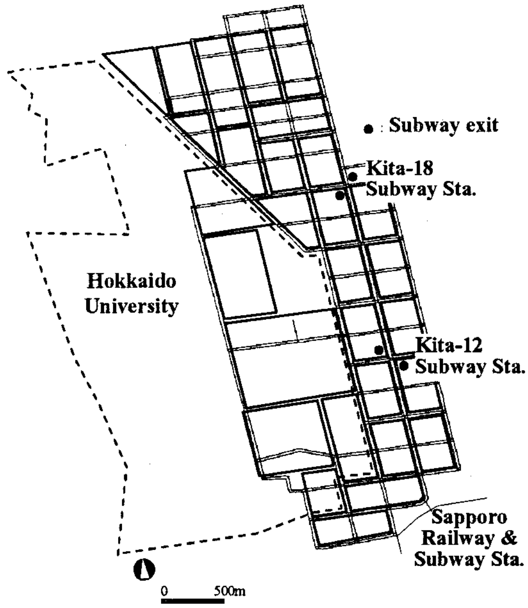


Figure 1: Range of the area undergone thorough field measurement

a) Measurement of Width and Separation

Lateral separation of the pedestrians is combined with the width of sidewalk because separation translates originally into the existence of a sidewalk. Three features are considered in separating pedestrians from motorized traffic[1].

- Buffer area: The distance between edge of pavement and sidewalk such as the width occupied by the trees, curb width
- Shoulder: width of shoulder or bike lane
- On-street parking: number of parked vehicles (parked legally or illegally)

Three levels were assigned: width exceeding 3 m and excellent separation (level 1), width of 1.5 to 3 m and reasonable separation (level 2), and width of less than 1.5 m and no separation (level 3).

b) Measurement of obstructions

Obstructions tend to influence pedestrian movement and reduce the effective walkway width. Therefore assessment of obstructions is essential to determine the access available to pedestrians[6), 11]. Improper utility poles, parked bicycles, building portions, pitting or unevenness of the road surface (such as potholes on the surface, missing portions of walkways, heaving pavements), improper boxes & vending machines, store displays, gas pumps, on street cafes, garbage station, and vehicles blocking on sidewalks were considered as obstructions. First they were counted on the path being assessed and then they were expressed in terms of the number of obstructions per 100 m. Three levels were assigned: no obstructions (level 1), 1 to 5 obstructions per 100 m (level 2), and more than 5 obstructions per 100m (level 3).

c) Measurement of flow rate

Dynamic characteristics are those that tend to change with traffic conditions, whereas static characteristics are those that are relatively stable[12]. Therefore it is highly desirable that flow rate be collected concurrently with what is being observed by the pedestrians. Normally minimum capacity of a line defines the capacity of a line. Based on this principle, field survey was conducted in the morning peak hour, so that each segment would be assigned the lowest grade. Flow rate was measured by standing at a point on the sidewalk at a given time. Since the peak flow rate was observed in the morning, all the flow rate measurements were conducted from 8:20 to 8:45AM. The range of flow rate for each level was assigned based on HCM 2000. Level 1 refers to pedestrian flow rate of less than 24 pedestrians/min/m, level 2 to a flow rate of 24 to 49, and level 3 to a flow rate of more than 49.

d) Measurement of number of bicycle passing and opposing events

By counting the number of passing and opposing bicycles for a particular time period, we could calculate the total number of bicycle passing and opposing events, per hour, for the average pedestrian on the shared path[13]. The equation given in HCM was used.

Total number of events $F = Q_{sb}(1 - S_p / S_b)*(2.4/W_E) + 0.5\, Q_{ob}(1 + S_p/S_b)*(2.4/W_E)$ (1)

Where

Q_{sb} = Bicycle flow rate in the same direction (bicycles/h)

Q_{ob} = Bicycle flow rate in the opposing direction (bicycles/h)

W_E = Width of sidewalk, S_p = Mean pedestrian speed (m/s), and S_b = Mean bicycle speed (m/s)

Level 1 refers to less than 61 bicycle events per hour, level 2 has a range from 61 to 144 events per hour, while more than 144 bicycle events per hour were assigned to level 3.

(2) Calculation of total utility

Conjoint analysis estimates an individual's 'value system', which specifies how much value a user puts on each level of the attributes[14]. 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. We established 4 attributes and 3 levels for each attribute by referring to LOS standards. The conjoint procedure was carried out to estimate the utility values for each attribute level. A minimum number of cards called profiles were generated by SPSS conjoint. 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. One thousand (1000) questionnaires containing those 11 profile cards were distributed in the study area which covers within and surrounding of Hokkaido University as shown in Figure 1. Respondents were asked to express their view of the sidewalks shown in the profiles by giving a rating on a scale. Respondents had to rate each profile from 0 to 10, with 10 being the best and 0 being the worst. This scale asks how likely they would be to use a sidewalk with given specifications on that profile. The respondents were requested to return the answered questionnaires by mail. The total number of recovered questionnaires was 281. Multiple regression analysis with dummy variables was used to calculate the utility values. If an attribute has m levels then it is coded in terms of (m–1) dummy variables. In this calculation, the independent variables were eight dummy variables, 2 for each attribute. The multiple regression model can be represented as

$$y = b_0 + b_1 d_1 + b_2 d_2 + b_3 d_3 + b_4 d_4 + b_5 d_5 + b_6 d_6 + b_7 d_7 + b_8 d_8 \quad (2)$$

Where, d_i (i =1 to 8) = dummy indicator variables representing attributes and b_i (i =1 to 8) = Unknown coefficient for d_i. The unknown coefficients were estimated using regression as in Table 1.

Table 1: Estimated coefficients of each dummy variable and the corresponding t-statistics

Parameter	Coefficients	Std. Error	t-value	Significance level
b_0	-1.10	0.124	-8.83	0.00
b_1	2.88	0.101	28.48	0.00
b_2	1.67	0.101	16.52	0.00
b_3	1.52	0.101	15.00	0.00
b_4	0.79	0.101	7.77	0.00
b_5	3.09	0.101	30.55	0.00
b_6	1.61	0.101	15.86	0.00
b_7	2.86	0.101	28.28	0.00
b_8	0.57	0.101	5.60	0.00

Each coefficient of dummy variables represents the difference in utilities for that level minus the utility for the base level. We used level 3 as the base level for coding the levels in terms of dummy variables. For example, for the first attribute 'width & separation' we can have the following two expressions.

$$U_{11} - U_{13} = b_1 = 2.88 \quad (3)$$

$$U_{12} - U_{13} = b_2 = 1.67 \quad (4)$$

Where, U_{ij} is the utility value of j^{th} level of i^{th} attribute. To solve for the utility, an additional constraint is necessary. The utilities are estimated on an interval scale, so the origin is arbitrary. Therefore, the additional constraint was established in the form of an equation shown below.

$$U_{11} + U_{12} + U_{13} = 0 \qquad (5)$$

By solving these three equations we could have $U_{11} = 1.36$, $U_{12} = 0.15$, and $U_{13} = -1.52$. Similarly, the utilities for the other attributes can be estimated. Figure 2 shows the utility values for each level obtained from conjoint analysis. Once we have the utilities for each attribute level, we can determine the total utility of a product or service by summing the utilities across all the attributes which define that product or service.

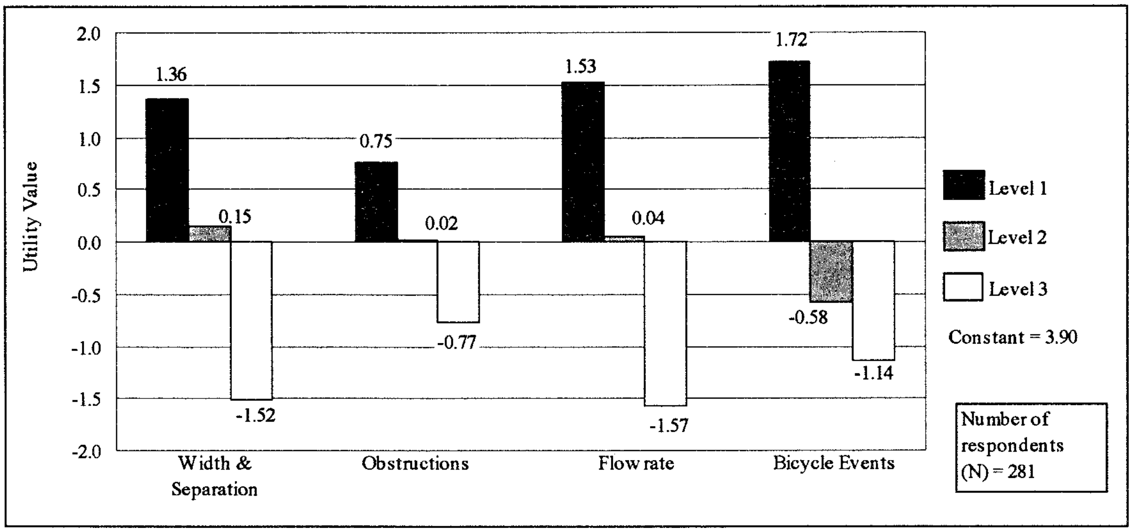


Figure 2: Utility values for each level of sidewalk

Table 2: Total utility values of some selected sidewalks

Loca-tion	Side-walk	(1) Width & Separation*				(2) Obstructions**						(3) Flow rate					(4) Bicycle Events			Level				Utility				Total Utility
		SW	SH	BZ	OP	P	PB	BP	MV	SD	O	Ped. ->	Ped. <-	Cyclists ->	Cyclists <-	ped/min/m	Fp	Fm	Fp + 0.5Fm	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	
1	1	1.8	0.0	0.7	2	5	1	2	0	0	0	5	0	13	0	10.36	255	0	255	2	2	1	3	0.15	0.02	1.53	-1.14	4.46
1	2	2.7	0.0	1.0	1	7	4	2	4	1	0	28	7	6	6	9.49	74	123	136	1	3	1	2	1.36	-0.77	1.53	-0.58	5.44
1	3	3.3	0.4	1.0	12	4	0	5	2	1	0	75	1	25	1	15.65	235	16	243	1	3	1	3	1.36	-0.77	1.53	-1.14	4.88
1	4	3.5	0.0	0.0	0	6	0	5	2	1	0	29	5	9	30	10.86	56	309	210	2	3	1	3	0.15	-0.77	1.53	-1.14	3.67
1	5	3.8	0.0	0.0	1	10	1	0	0	1	1	1	17	19	6	6.21	108	57	136	2	3	1	2	0.15	-0.77	1.53	-0.58	4.23
1	6	5.5	1.1	3.4	0	18	0	0	0	0	0	0	4	1	11	4.95	10	189	105	1	3	1	2	1.36	-0.77	1.53	-0.58	5.44
2	1	3.5	0.0	1.3	1	4	0	0	0	0	0	17	5	3	2	3.87	30	33	46	1	2	1	1	1.36	0.02	1.53	1.72	8.53
2	2	3.2	0.4	1.2	0	8	0	5	2	1	1	0	5	1	6	4.71	15	154	93	1	3	1	2	1.36	-0.77	1.53	-0.58	5.44
2	3	3.5	0.0	1.0	2	5	0	0	0	4	1	10	10	5	2	5.65	64	42	85	1	2	1	2	1.36	0.02	1.53	-0.58	6.23
2	4	3.4	0.0	1.0	0	4	0	1	1	5	1	0	0	9	2	4.89	108	40	128	1	3	1	2	1.36	-0.77	1.53	-0.58	5.44
2	5	3.3	0.0	0.0	0	10	4	1	0	1	1	2	5	14	16	11.04	131	250	257	2	3	1	3	0.15	-0.77	1.53	-1.14	3.67
3	1	2.0	0.0	1.5	2	5	1	1	1	1	0	8	5	12	9	43.11	576	720	936	1	2	2	3	1.36	0.02	0.04	-1.14	4.18
3	2	3.4	0.4	1.1	1	4	2	0	2	1	0	29	8	12	17	24.48	207	490	452	1	2	2	3	1.36	0.02	0.04	-1.14	4.18
3	3	3.5	0.0	0.0	7	8	0	3	1	0	0	9	2	6	5	4.15	49	68	83	1	3	1	2	1.36	-0.77	1.53	-0.58	5.44
3	4	2.2	0.5	0.0	4	4	84	0	2	7	3	190	36	8	2	24.18	79	33	95	2	3	2	2	0.15	-0.77	0.04	-0.58	2.74
3	5	3.1	1.4	1.4	0	7	1	1	0	1	3	16	2	27	10	47.43	833	514	1090	1	3	2	3	1.36	-0.77	0.04	-1.14	3.39
3	6	4.1	0.6	0.0	0	7	0	0	0	0	1	7	4	13	8	4.66	69	71	104	2	2	1	2	0.15	0.02	1.53	-0.58	5.02
4	1	2.8	1.1	0.0	0	0	0	0	0	0	0	6	3	23	27	14.93	177	347	351	2	1	1	3	0.15	0.75	1.53	-1.14	5.19
4	2	0.1	0.0	0.0	0	0	0	0	0	0	0	2	0	2	4	52.00	432	1440	1152	3	1	3	3	-1.52	0.75	-1.57	-1.14	0.42
4	3	2.9	0.0	0.0	0	1	0	0	0	0	0	6	3	1	1	1.17	7	12	14	2	2	1	1	0.15	0.02	1.53	1.72	7.32

* SW: Sidewalk (m)
SH: Shoulder (m)
BZ: Buffer zone (m)
On-street parking

** P: Poles
PB: Parked bicycles
BP: Building portions
MV: Mailboxes & vending machines
SD: Store displays
O: Others

Total utility can be defined as a number which represents the overall value that users place on a product or service. A low value of total utility indicates less value and a high total utility indicates more value. In the same manner, high LOS indicates a performance level near perfect conditions and low LOS describes degrees of unacceptable performance level. Therefore an assumption is made that there is a linear relationship between the total utility of a specified sidewalk and its LOS grade.

In this research, after determining the level of each factor to a specified sidewalk, utility values were assigned to each factor according to its level. Then the total utility was calculated by adding the utilities assigned to each factor according to its level. For example, the total utility of a sidewalk with more than 3m wide & excellent separation (level 1), more than 5 obstructions per 100m (level 3), flow rate: less than 24 pedestrians/min/m (level 1), and from 61 to 144 bicycle events/hour (level 2) is:

Utility (more than 3m wide & excellent separation) + utility (more than 5 obstructions per 100m) + utility (flow rate: less than 24 pedestrians/min/m) + utility (from 61 to 144 bicycle events/hour) + constant

= (1.36) + (-0.77) + (1.53) + (-0.58) + (3.90) = 5.44.

Sample results from the field measurements are shown in Table 2.

(3) Survey with pedestrians

a) Selected locations

Pedestrians were surveyed at four locations shown in Figure 3. These four field locations were chosen from the study area such that each would have a different grade of sidewalk. Each location includes 5 or 6 sidewalk segments. The first location includes four sidewalk segments in the third block and two sidewalks on the Hokkaido University campus. Since this location was near the Kita-12 subway station, a high pedestrian flow rate was observed in the morning rush hour. The second location was adjacent to first location covering 2 blocks. The field measurements indicated that the overall LOS grades of sidewalk segments had a very wide range at this location. Two sidewalks were observed to have very high LOS and one to have low grade among the selected sidewalks. The third location was near to Sapporo railway station. At this location even though the sidewalks are very wide and in excellent condition, field survey showed low LOS grades because of closer interactions among pedestrians. The fourth location was chosen inside the Hokkaido University premises. At this location, the pedestrian environment differs from those at other locations. All the intersections are unsignalized and are designed to give priority to pedestrians, allowing people to cross at any time without waiting.

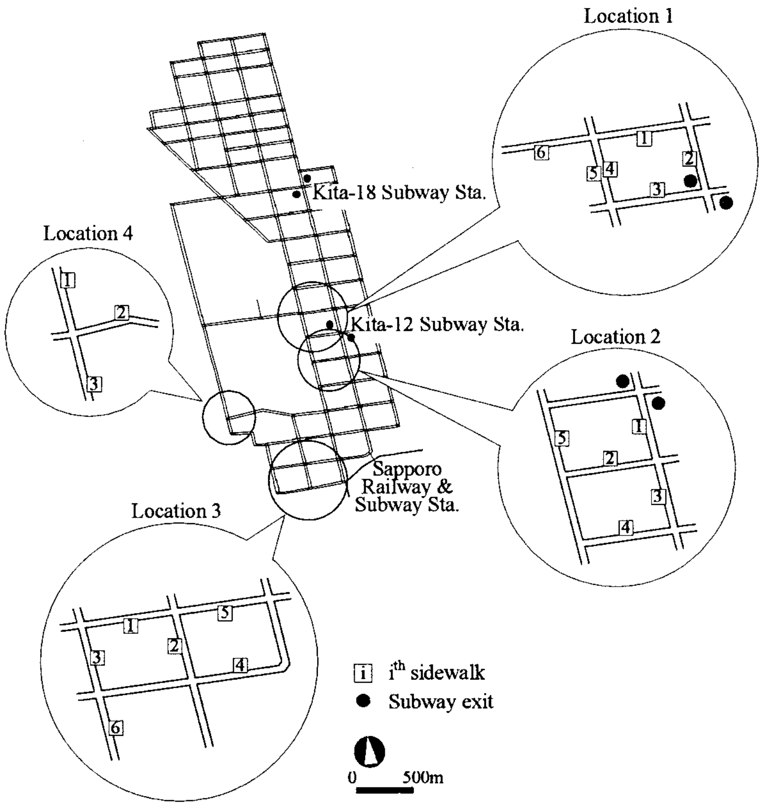


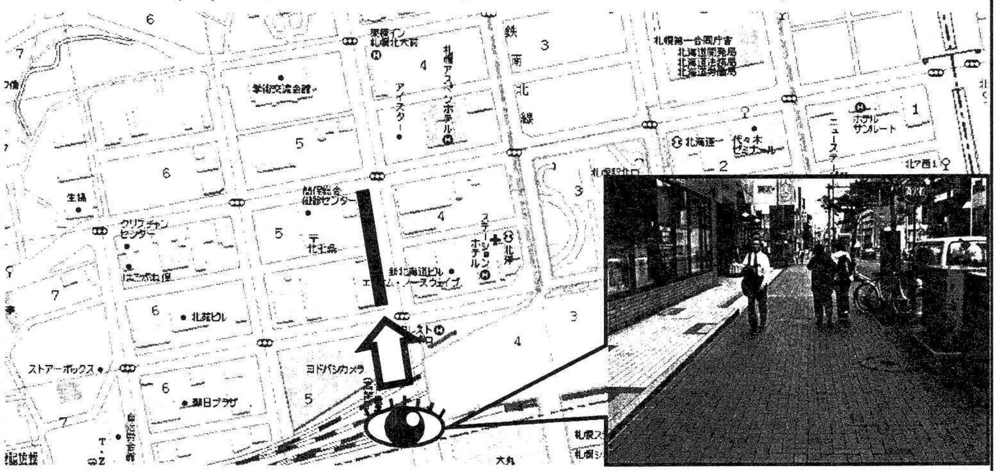
Figure 3: Selected locations for the questionnaire survey

b) Questionnaire design and survey

Photos of sidewalks were used to make questionnaires and the locations of sidewalks were indicated on maps. Figure 4 shows a sample questionnaire sheet used for the survey. Instructions and explanations of LOS were given in the first few pages of questionnaire in order to clarify what was expected from respondents. Questionnaires were distributed to the pedestrians walking along the sidewalks. Respondents were requested to record their perceptions on a scale that indicated the ease of walking on that sidewalk. The major advantage of this approach is that perceptions are based on walking experiences in real situations. Respondents were given enough time to answer the questions. To simplify the matter of providing an assessment, the scale was made ranging from 0 to 10, with 10 indicating great ease of walking and 0 indicating great difficulty of walking. In addition to their perceived LOS of the indicated location, the respondents were also asked to indicate how often they used the path.

Approximately how many times do you walk along this sidewalk?

①Almost every day ②Few times a week ③Few times a month ④Few times a year



Imagine that you are walking along this sidewalk on a weekday in the morning.
How do you feel when you use this sidewalk?

Difficult to walk |—+—+—+—+—+—+—+—+—+—| Comfortable to walk

Figure 4: Sample questionnaire sheets used for validation survey (Location No. 3, Sidewalk No. 4)

3. Results

(1) Age distribution and gender of participants

A total of 252 participants responded to the survey, 157 males and 95 females. Table 3 shows their age distribution, which was broken into six age cohorts. The result indicates that a wide range of respondents participated.

Table 3: Age distributions of surveyed respondents

Location	Total number of participants	Age					
		Under 20	20-29	30-39	40-49	50-60	Over 60
1	74	6	21	13	18	13	4
2	52	3	16	6	12	9	6
3	61	1	7	7	12	16	17
4	65	1	13	12	10	27	2

(2) User scores

Responses from persons who were unfamiliar with the location or who only walked there a few times per month or year were excluded. Only responses from frequent users were analyzed. Since there is a range of possible user scores for each sidewalk, an average (mean) value is necessary in order to assign a certain aggregate value of user score to each sidewalk. Table 4 shows the averages of user scores that were computed for each sidewalk from survey responses. The averages of user scores were compared with the total utility values that were calculated from the field measurement data. However, the average value alone does not convey information on the degree of accuracy of the point estimates of the mean. Besides the average value, the next most important quantity of a random variable is its measure of standard deviation. Standard deviation gives a measure of how closely the values of the variate are clustered around the mean value[16]. For this reason, standard deviation of each average value was computed as shown in Table 4. Pair wise data for the two variables, total utility values And averaged user scores plotted on a two-dimensional graph, appear as in Figure 5. This figure shows that there is a general tendency for the user scores to increase with increasing values of total utility. The correlation coefficient (R) between total utility and user scores is 0.82. This confirms that the total utility values can be used to predict the overall LOS of the sidewalk environment.

(3) Hypothesis test

Often the problem of analyzing the quality of the estimated regression line is handled through an analysis-of-variance (ANOVA) approach[15]. We used ANOVA to test the hypothesis which relates to the significance of regression. A decision to reject null hypothesis (H_o) implies an acceptance of alternative hypothesis (H_1). The analysis of variance is summarized in Table 5. In Table 5, the computed F-statistic, F = 35.687, exceeds the critical value $F_{0.01,\,1,\,18}$ = 8.285, therefore the null hypothesis, H_o: $\beta_1 = 0$, is rejected for a significance level of α = 0.01. Rejecting null hypothesis implies that there is linear relationship between total utility value and user score. This result indicates that the null hypothesis is rejected for a significance level equal to 1 percent. It means that the computed F values are incompatible with the null hypothesis; that is, we will reject H_o and conclude that the alternative hypothesis is true. Now, it can be concluded that total utility is of value in explaining the variability in user scores for sidewalks.

Table 4: Averages of user scores

Location	Sidewalk	Total Utility	Number of Participants	Average Users' Score	Std Dev
1	1	4.46	33	3.58	2.26
	2	5.44	47	5.30	2.87
	3	4.88	37	4.32	2.81
	4	3.67	51	4.51	2.68
	5	4.23	49	4.33	2.66
	6	5.44	40	6.20	2.73
2	1	8.53	25	7.08	2.23
	2	5.44	8	6.00	1.60
	3	6.23	13	6.77	1.48
	4	5.44	5	5.00	1.00
	5	3.67	8	4.00	1.93
3	1	4.18	25	5.08	2.22
	2	4.18	35	5.49	2.78
	3	5.44	25	5.64	2.80
	4	2.74	41	2.20	2.08
	5	3.39	22	4.45	2.54
	6	5.02	21	4.86	2.74
4	1	5.19	29	7.21	2.02
	2	0.42	9	3.11	3.59
	3	7.32	42	7.88	2.33

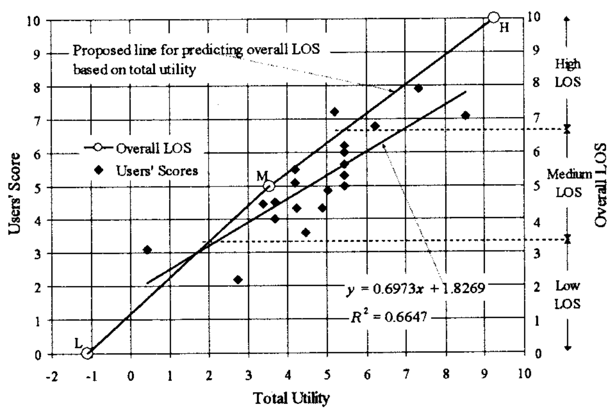


Figure 5: Utility values versus user scores

Table 5: Analysis-of-variance (ANOVA) for testing $\beta = 0$

Source of Variation	Sum of Squares (SS)	Degree of Freedom (df)	Mean Square (MS)	Computed F
Regression	26.1181	1	26.1181	35.6886**
Residual Error	13.1730	18	0.7318	
Total	39.2910	19		

4. Discussions and Conclusions

A term called 'overall LOS' was defined and used to combine the factors affecting pedestrian LOS. Even though HCM 2000 provides LOS analysis for each factor, there is no description of how to combine LOS of each factor for an overall LOS of pedestrians. Using overall LOS makes it much easier to understand how well a particular street accommodates pedestrian travel, rather than LOS of individual factors. In other words, the concept of overall LOS may provide an easy understanding about the overall condition of a pedestrian walkway. In this research, a methodology was developed for estimating the overall LOS of pedestrian walkways based on total utility value. Site characteristics were collected to calculate the total utility values for each sidewalk. The level of each factor to a specified sidewalk was determined using field measurement data. Utility values from a conjoint analysis were assigned to each factor according to the factor's level. Then the total utility was calculated by adding the utilities assigned to each factor according to its level.

According to conjoint analysis theory, a product or service that receives a higher total utility value than any other product or service will be considered the most valuable of the products or services. In contrast, a product or service that receives a low total utility value will be considered to have a low use value. This means that the maximum total utility is an upper limit of overall LOS and the minimum total utility is a lower limit of overall LOS. The summation of utility values corresponding to medium level of each factor will be the total utility value for the medium LOS. A graph was plotted by using the three total utility values corresponding to high, medium and low LOS. Then a line was drawn connecting 3 points; H (maximum total utility, upper limit of overall LOS), M (the summation of utility values corresponding to medium level of each factor, medium overall LOS), and L (minimum total utility, lower limit of overall LOS) as indicated in Figure 5. It was observed that these three points to form an almost straight line. Therefore it was assumed that there is a linear relationship between the total utility of a sidewalk and the overall LOS of that sidewalk. To clarify this assumption a validation process was conducted. Real pedestrians were surveyed and their evaluations were collected in the form of scores. The total utility values were calculated from the field measurement data and the scores given by path users at selected sidewalks were compared. Results shown in Figure 5 indicate that the total utility value has a linear relationship with overall LOS. From this behavior we may conclude the total utility value is an accurate indicator of overall LOS of pedestrians. Furthermore, the method proposed in this study for the assignment of overall LOS to pedestrian walkways may be useful in producing maps that show pedestrians the overall LOS on each roadway segment. Although this study proposed a method of determining overall LOS, it did not include all factors affecting pedestrian LOS. A fuller and broader consideration of all such factors is necessary.

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Method to Determine Overall Level-of-Service of Pedestrian Walkways Based on Total Utility Value*

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This research proposes a method to estimate the overall level-of-service (LOS) of pedestrian walkways. It is based on the concept of total utility value, which comes from a conjoint analysis research. To estimate the total utility value for pedestrian walkways, field measurements were carried out by collecting operational and geometrical characteristics of sidewalks. Calculated total utility values were used to assign an overall LOS designation to each sidewalk, based on an assumption of a linear relationship between total utility value and overall LOS. To validate this calculation method, a pedestrian survey was conducted. The scores given by the pedestrians had a linear correlation with the overall LOS assigned for each sidewalk based on total utility value. This indicates that the total utility value can be used as an index of the overall LOS of pedestrian walkways.

歩道の構成要因に対する利用者の効用に基づくサービスレベル評価*

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本研究は、歩道の総合サービスレベルを評価する手法を提案したものである。これはコンジョイント分析から得られた、歩道を構成する複数の要因に対する効用値に基づいている。これら効用値を求めるために、歩道の物理的な諸構成要因の水準データを得るためのフィールド調査を行った。歩道構成要因の水準に相当する効用値を算出したのち、この結果を各歩道の総合サービスレベルに割り当てた。これは効用値と総合サービスレベルが線形の関係にあるという仮定に基づいている。この算出過程を検証するために、歩行者に対してアンケート調査を実施した。ここから、歩行者が利用している歩道に対して与えた得点は、先の効用値から得られた総合サービスレベルと十分な線形関係にあることがわかった。これにより、効用値は歩道の総合サービスレベルに対する指標として利用可能であることを示した。