

# INVESTIGATING STRUCTURAL RELATIONSHIPS AMONG PEDESTRIAN PERCEPTION, BEHAVIOR, TRAFFIC, AND LEVEL OF SERVICE\*

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## 1. Introduction

Sidewalk performance can be assessed by many ways, such as based on pedestrian/vehicle traffic, physical geometry, environment, and user perceptions. Most of previous sidewalk performance studies were performed using quantitative variables such as pedestrian space, pedestrian and/or vehicle traffic, and sidewalk width<sup>1)-2)-3)</sup>. Pedestrian opinions can be used for determining adequate levels of service from the road user's perspective. Some previous studies considered qualitative variables to determine level of service. For instance, Tan et al.<sup>4)</sup> collected pedestrian perceptions about their feelings of safety and comfort, although the pedestrian level of service model was proposed based on quantitative variables, including bicycle traffic, pedestrian traffic, vehicle traffic, driveway access quantity, and distance between sidewalk and vehicle lane. Sarkar<sup>5)</sup> introduced some theoretical guidelines for qualitative evaluation of the levels of comfort offered along walkways in major activity centers (urban areas). Observations from urban design, environmental psychology, landscape architecture and urban planning were utilized in the study. The method is expected to offer a useful framework to assess comfort requirements in order to efficiently provide pedestrian circulation system in major activity centers. In a similar vein, Jaskiewicz<sup>6)</sup> proposed a method for evaluating pedestrian LOS based on trip quality. Nine specific items were measured for evaluating pedestrian systems in terms of pleasantness, safety and functionality. The research revealed that pedestrian level of service needs more than volumes and capacities. To make walking a more attractive mode of transportation, it was essential to pay more attention to pedestrian comfort and safety in addition to volume and capacity factors. Rahaman<sup>7)</sup> tried to explore the qualitative level of comfort of pedestrians in Dhaka City by offering six broad categories of roadside walking environment in terms of safety, security, convenience and comfort, continuity of the walkway, system coherence and attractiveness of some specific facilities. Similarly, Kim et al.<sup>8)</sup> studied the impact of street furniture on pedestrian level of service in Waikiki, Hawaii. The impact of fourteen differences furniture was observed and results revealed that the larger the dimension of the street furniture, the greater the impact on pedestrian level of service.

Generally, studies described above considered pedestrian opinions regarding sidewalk performance; however, such opinions did not include as one of the variables in the level of service model<sup>4)-6)-7)</sup>. In some studies, only safety and comfort of pedestrian were considered as important aspects<sup>4)-5)-7)</sup>. Considering pedestrian opinions about behavior, traffic, and sidewalk performance as qualitative variables, this paper attempts to examine potential relationships among those variables and level of service. In this study, field observations are performed in the sidewalk where street vendors exist along the sidewalk. Therefore, pedestrian opinions would incorporate street vendors presence in correlation with sidewalk level of service. Street vendors are considered important factors in the present research because it is a unique characteristic in the sidewalk particularly in some developing countries. Therefore, this research can be considered the first step to establish the level of service model that considers qualitative variables based on pedestrian perception, especially regarding the existence of street vendors.

The key objective of this study is to examine relationships among pedestrian traffic, behavior, perception, and pedestrian level of service in the sidewalk performance context. Data collection was performed in Bang Rak area, one of the commercial areas in Bangkok, Thailand.

This paper contains five chapters. Chapter one introduces the research problem, followed by chapter two that explains theoretical background. Chapter three describes proposed methodology that comprises hypothesis, analytical tools, and research method used in this research. Research results are discussed in chapter four. Finally, chapter five describes discussion and conclusion.

## 2. Theoretical Background

### (1) Pedestrian Level of Service

In general, level of service (LOS) is a qualitative measurement to explain operational conditions of transportation facilities, such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience<sup>3)</sup>. The level of service is usually designated with letters ranging from LOS A, representing good operating conditions with

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little or no delay, to LOS F that represents stop-and-go conditions with frequent and long delays<sup>3)</sup>. Level of service is employed to simplify complex numerical performances into a letter grade system that represents travelers' perceptions regarding quality of service provided by the facilities<sup>9)</sup>. In case of pedestrian facilities, level of service is a kind of qualitative measurement of pedestrian facilities (sidewalks) to serve the pedestrians.

The Federal Highway Administration (FHWA) has developed a method for assessing pedestrian level of service as one of chapters in the Highway Capacity Manual 2000<sup>3)</sup>. This method provides an outline for evaluating pedestrian facilities. Under this context, uninterrupted pedestrian facilities are both exclusive and shared pedestrian path (indoor or outdoor) designed for pedestrian usage. Walkways and sidewalks are the uninterrupted pedestrian facilities that pedestrians are separated from vehicular flows and they can be disrupted only by interactions with other pedestrians. The assessment of walkways is based on some variables, namely, effective walkway width, walking speed, pedestrian space, and pedestrian flow.

## (2) Pedestrian Behavior and Attitude

Literature review indicates that the crucial components affecting pedestrian travel behavior are environmental designs and urban forms. Walking activity can be encouraged by a proper design of pedestrian facilities without compromising safety, comfort, and convenience<sup>10)</sup>. Also, improvement in walking facilities to increase safety and comfort for pedestrians can be performed without significant side effects on vehicle travel<sup>11)</sup>. Therefore, physical facilities should be provided. Examples are roadways, sidewalks, and medians that can encourage pedestrian traveling. Improvement in comfort and convenience can be obtained through separation of pedestrian and vehicle traffic, control of flow of pedestrians and vehicles, improvement of visibility, proper communication through signs, and assistance of pedestrians with special needs.

Although some studies have focused on the problem of pedestrian safety<sup>12)</sup>, there are still limited studies in the literature on pedestrian perceptions and attitudes regarding their facilities, such as a study about impact of traffic on behavior and perceptions of safety of pedestrians<sup>13)</sup> and a study about the sufficiency of crossing facilities and the willingness of pedestrians to use them<sup>14)</sup>.

## (3) Pedestrian Traffic

The basic principle of pedestrian flow is generally similar to vehicular flow in terms of the freedom to select speed and to overtake others. However, pedestrian flow includes the ability to cross pedestrian traffic stream, to maneuver and to change in speed for avoiding conflict, and to walk in reverse direction facing major flow<sup>3)</sup>.

Environment factors that have contribution to the walking experience and influence the level of service include the comfort, convenience, safety, and security of the walkway system. Items that influence the comfort factors are weather protection, climate controls, arcades, transit shelters, and other pedestrian amenities. Convenience factors comprise items such as walking distances, pathway direction, grades, sidewalk ramps, directional signing, etc. Separation of pedestrians from vehicular traffic on the same horizontal plane, providing traffic control devices for time separation between pedestrian and vehicular traffic, providing underpasses and overpasses, are considered important regarding safety features. Security factors deal with good lighting, open lines of sight, and the degree and level of street activity. Supplemental factors explained above can influence pedestrian perceptions on the overall quality of the street environment<sup>3)</sup>.

## (4) User Perceptions in Transportation Facilities

Transportation users are considered one of important aspects in facility assessment. Nakamura et al.<sup>15)</sup> studied interrelationships among three variables on rural motorways, namely traffic flow conditions, driving behavior, and degree of drivers' satisfactions. The research used quantitative variables including traffic volume, vehicles' speed, lane utilization ratio, lane changing, adjustment of acceleration and adjustment of spacing. The degree of driver's satisfaction is a qualitative variable derived from a questionnaire survey of drivers' evaluation of the traffic flow condition, driver characteristics, and vehicles' characteristics. The method of successive intervals is used for quantifying degrees of drivers' satisfaction. Analysis on the factors affecting the degree of drivers' satisfaction was conducted based on multiple linear regressions. Another method for determining relationships between traffic flow and degree of satisfaction was simple linear regression. Nakamura et al.<sup>15)</sup> revealed that traffic flow rate was the strongest factor towards the degree of drivers' satisfaction, while other variables affecting traffic conditions were the number of lane changing, the elapsed time of car-following situation, and the driving experience.

Pamanikabud et al.<sup>16)</sup> introduced a serviceability index in order to be used as a quantitative index for evaluating walkways' serviceability using utility theory approach. The research takes into account two main aspects, i.e. physical aspects (width, height, and surface materials) and environmental aspects (damage, continuity, lighting, route map, air and noise pollution). Pedestrian interview was performed in order to weigh the factors of each parameter. Statistical method was then adopted to analyze the mean and standard deviation of each of these parameters based on the estimated percentage numbers from all of the 250 sets of questionnaires. This research concluded that developed serviceability index can be used effectively in the quantitative evaluation of walkway serviceability that includes both quantitative and qualitative parameters for walkways around the Bangkok Mass Rapid Transit stations.

Burde<sup>17)</sup> studied road user perceptions and characteristics to assess overall perceptions of highway maintenance service quality. The research applied road user interview for evaluating three factors, namely, tangible (physical

facilities, equipment, and appearance of personnel), reliability (ability to perform the service dependably), and assurance (knowledge of employees and their ability to inspire trust and confidence). A factor analysis was used to determine significant variables in the service quality evaluation. Multiple linear regression and cumulative logit model regression were used to derive level of service quality. Among the main finding of this research, safety and reliability were the most significant service dimensions.

#### (5) Relationships among Variables

Several research studies had been undertaken regarding relationships among behavior/attitude, traffic, perception, and level of service. Although some of the studies were not investigated in the pedestrian context, it is apparent in the past studies that pedestrian behavior influenced pedestrian perceptions. Walking environments establish a set of conditions for behavior. Once exposed in the public environment, pedestrians experienced a variety sensation related to comfort or stimulation and they had to make a series of judgments and decisions while navigating the environment<sup>18)</sup>. Tan et al.<sup>4)</sup> studied the relationships between pedestrian behavior and level of service by observing pedestrian attitudes toward obstructions on the sidewalk. Results revealed that 80% respondents agreed that obstructions on the sidewalk influenced to level of service. Also, it can be implied that traffic condition influenced perceptions and level of service.

Some studies proposed relationships between pedestrian perceptions and level of service. For example, Landis et al.<sup>2)</sup> revealed that perceptions about safety and comfort were considered significant factor for assessing level of service. Jaskiewicz<sup>6)</sup> collected pedestrian perceptions regarding nine variables of trip quality. The nine measures were used to identify and to classify the characteristics or features that contribute to positive pedestrian experiences.

### 3. Methodology

Based on extant literature review in the previous chapter, the current study proposes the conceptual model as seen in Figure 1. The proposed relationships consist of four latent variables, namely, pedestrian behavior and attitude, pedestrian traffic, pedestrian perception about sidewalk condition, and pedestrian level of service. Table 1 presents corresponding hypotheses to be tested. Regarding behavior, this research assesses pedestrian opinions toward their behavior when pedestrians are encountered at the sidewalk with street vendors. The present study is based on the evaluation of pedestrian opinions in a commercial area with many stores and street vendors along the sidewalk.

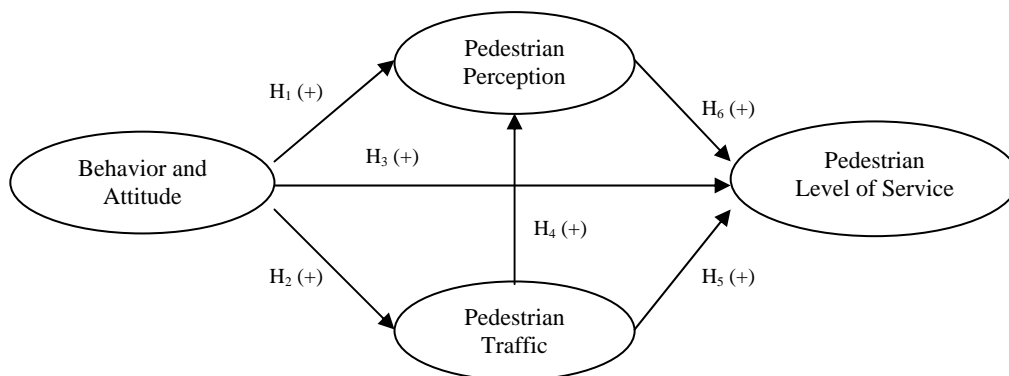


Figure 1: Proposed hypothetical model

Table 1: Hypotheses of relationships among latent variables

Hypothesis	Relationships
H <sub>1</sub>	Pedestrian behavior & attitudes have a positive effect on pedestrian perception
H <sub>2</sub>	Pedestrian behavior & attitudes have a positive effect on pedestrian traffic
H <sub>3</sub>	Pedestrian behavior & attitudes have a positive effect on pedestrian level of service
H <sub>4</sub>	Pedestrian traffic has a positive effect on pedestrian perception
H <sub>5</sub>	Pedestrian traffic has a positive effect on pedestrian level of service
H <sub>6</sub>	Pedestrian perception has a positive effect on pedestrian level of service

To test the proposed relationships, a multivariate analytical technique, the structural equation modeling (SEM), was used. SEM is a confirmatory method that takes a hypothetical testing approach to a theory and evaluates causal relationships between constructs of a model. The SEM approach refers to a series of statistical methodologies used to analyze data. The series include path analysis, confirmatory factor analysis (CFA), and structural regression models. Furthermore, the SEM consists of two components, a measurement model and a structural model. The measurement model assesses latent (unobserved) variables as linear functions of indicators (observed variables), while the structural model shows the directions and strengths of the relationships of latent variables.

## (1) Analytical Tools

### a) Exploratory factor analysis

Factor analysis is a statistical approach that can be used to verify the conceptualization of a hypothesis by analyzing interrelationships among a large number of variables. The objective is to explain these variables in terms of their commonness underlying dimensions by condensing the information contained in a number of original variables into a smaller set of dimensions with a minimum loss of information<sup>19)</sup>. Factor analysis can also be used to determine the relative importance amongst these dimensions.

The Kaiser–Meyer–Olkin (KMO) test and/or the Barlett’s test of sphericity can be undertaken for examining the interview data to see whether it is appropriate to use factor analysis. These two tests examine the strength of the relationships among variables and provide a minimum standard that should be passed before a factor analysis is performed. The KMO measure of sampling adequacy is an index for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. Its value should be greater than 0.5 for a satisfactory factor analysis to proceed<sup>20)</sup>.

### b) Structural equation modeling

Structural equation modeling (SEM) with latent variables is a method of multivariate statistical analysis capable of measuring the underlying latent construct identified by factor analysis and assessing the path of hypothesized relationship between the constructs<sup>19)</sup>. Advantages of SEM are parsimony, ability to model complex systems, and ability to model relationships among non-observable variables while taking measurement errors into account.

A structural equation model is first specified to account for the measurement relationships from latent (unobserved) variables to observable variables. In this study, the latent variables are the four perception dimensions, and the observed variables are eighteen perception items and seven factors from factor analysis. The relationships among latent variables cannot be tested until a well-fitting model has been reached. In this case, the relationships among pedestrian opinions about behavior, traffic, perceptions of sidewalk condition, and perceptions of sidewalk performance are of interest. This modeling sequence stresses the importance of the goodness of fit assessment and of the re-specification of bad-fitting models.

The  $\chi^2$  statistics should be examined to check the overall fit of the structural model. However, rejection of a model on the basis of  $\chi^2$  statistic alone is inappropriate, though a significant  $\chi^2$  statistic indicates an adequate fit, but this statistic depends on sample size and model complexity. Therefore, other measures of fit dealing with sample size should be also applied. Examples are the goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normalized fit index (NFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). Hair et al.<sup>19)</sup> recommends that the acceptance of good fit to a model requires that the obtained GFI and AGFI, NFI, CFI values should be greater than or equal 0.90. In addition, an acceptable value of RMSEA should range from 0.05 to 0.08<sup>19)-21)</sup>.

## (2) Research Method

A review of the literature is undertaken to establish questions used in the questionnaire. The content validity of the questionnaire is deemed adequate. Part 1 of the questionnaire covers measurements of current sidewalk conditions with 27 attributes. These attributes are developed to measure pedestrian perceptions in five different areas: (a) safety/security, (b) comfort, (c) vendors attraction, (d) movement easiness, and (e) sidewalk performance. Respondents are asked to indicate the perceived agreement of each attribute using a seven-point Likert scale with “one” representing strongly disagree and “seven” representing strongly agree. Part 2 deals with the measurement of six items about traffic and geometric conditions, and twelve items about behavior and attitudes through the same scale used in Part 1. Part 3 solicits respondent’s profile information, such as gender, age, occupational status, education level, group walking, walking as main trip mode, frequency of walking, trip purpose, and monthly income.

A questionnaire survey was performed in order to collect empirical data from pedestrian that pass the sidewalk in Bang Rak area, Bangkok, Thailand. This location was chosen because of some reasons such as the number of pedestrian flow is considered high, street vendors exist along the sidewalk, and the sidewalk located in commercial areas. Figure 2 illustrates the sidewalk condition during observation.

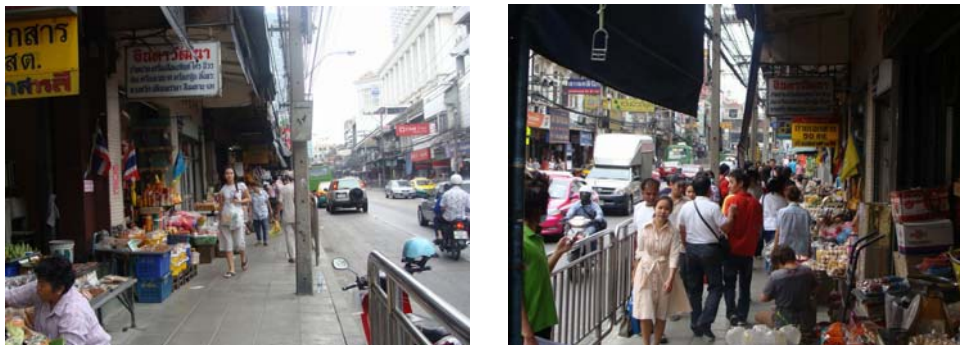


Figure 2: Sidewalk at Bang Rak area, Bangkok

The interview was conducted for 8 hours from 10.00 a.m. to 6.00 p.m. for two days during November 3-4, 2009. Out of 375 respondents, 340 usable samples were obtained, i.e. a 90.7% valid data rate. For structural equation modeling, the sample sizes be greater than 200 is required<sup>19)</sup>. The general rule for factor analysis is that five to ten observations are required for each variable/attribute to be analyzed<sup>19)</sup>. Therefore, these usable samples are considered adequate for use in structural equation modeling and factor analysis.

### (3) Respondent Characteristics

Pedestrian profiles are presented in Table 2. The percentage of female pedestrians (53.8%) is greater than male pedestrians (46.2%). The average age of the respondents is 34 years. Most of the respondents are workers (41.5%) and students (34.7%). Therefore, they used this sidewalk daily (62.1%), to/from work (29.4%) and to/from school (22.6%). However, 26.8% respondents are shoppers, which is reasonable because the sidewalk is located in commercial area.

Table 2: Pedestrian characteristics from survey samples

Attributes	Distribution	Frequency	Percent (%)
Gender	Male	157	46.2%
	Female	183	53.8%
	Total	340	100.0%
Age	< 18	49	14.4%
	18 - 30	148	43.5%
	31- 56	114	33.5%
	> 56	29	8.5%
	Total	340	100.0%
Occupation	Student	118	34.7%
	Administrative/office business	72	21.2%
	Factory employee	21	6.2%
	Government employee	18	5.3%
	Housewife	18	5.3%
	Retired	5	1.5%
	Unemployed	13	3.8%
	Self employee	30	8.8%
	Others	45	13.2%
	Total	340	100.0%
Frequency of walking on this sidewalk	Daily	211	62.1%
	6 times/week	1	0.3%
	5 times/week	5	1.5%
	4 times/week	4	1.2%
	3 times/week	9	2.6%
	2 times/week	8	2.4%
	1 times/week	1	0.3%
	Rarely	101	29.7%
	Total	340	100.0%
Trip purpose	Go to/from work	100	29.4%
	Go to/from school	77	22.6%
	Shopping	91	26.8%
	Recreational	16	4.7%
	Visiting friends/family	16	4.7%
	Others	39	11.5%
	multipurpose	1	0.3%
	Total	340	100.0%

## 4. Results

### (1) Underling Dimensions of Pedestrian regarding Current Sidewalk Conditions

The exploratory factor analysis was employed on the 27 items of sidewalk current conditions in order to extract dimensions of pedestrian perceptions. The KMO test resulted in a value of 0.87, which is greater than 0.5, so the factor analysis is justified<sup>22)</sup>. Using the method of principal component extraction with VARIMAX rotation, seven factors are identified important and labeled on the basis of the attributed covered (see Table 3). Variables with a factor loading greater than 0.5, are chosen<sup>19)</sup>. Therefore, one item with a factor loading less than 0.5 have been eliminated - namely, 'I feel comfortable walking through this sidewalk with the presence of on street vendors'. The seven factors explain 67.1% of total variance. Inspection of the output confirms that the seven-factor structures make conceptual sense and that each factor accounts for a substantial portion of the overall variance.

The resulting factor structures are presented in Table 3. These seven factors are arbitrarily named as comfort, accessibility, vendor's attraction, safety/security, vendor problems, space availability, and sidewalk performance.

Table 3: Factor structure of sidewalk conditions

Variables	Factor loadings	Variance explained (%)
<b>Factor 1: Comfort (FA_1)</b>		<b>28.941</b>
1 I am not impeded by other pedestrians	0.747	
2 I can move freely without obstruction from physically features (phone boxes, column, bench, etc)	0.739	
3 I can move freely without obstruction from vendors	0.683	
4 I think that the street vendors keep the sidewalk clean	0.680	
5 I think that the available sidewalk width can accommodate pedestrian flow	0.646	
6 I have enough space to avoid the vendor's obstruction without decelerating my pace	0.587	
7 I think that the sidewalk is flat enough to accommodate wheelchair users	0.558	
<b>Factor 2: Accessibility (FA_2)</b>		<b>12.647</b>
8 I think that I can enter/exit to/from this sidewalk easily	0.728	
9 At the crosswalk, sidewalks are at the same grade level as streets, so I can move easily for crossing roadway	0.683	
10 I can overtake other pedestrians easily	0.675	
<b>Factor 3: Vendor Attraction (FA_3)</b>		<b>7.001</b>
11 I intend to buy something from street vendors	0.846	
12 I am interested in goods sold by vendors along this sidewalk	0.808	
13 I enjoy vendor activities in this sidewalk	0.787	
<b>Factor 4: Safety/Security (FA_4)</b>		<b>5.552</b>
14 I feel safe from trips, slips and falls	0.814	
15 I feel safe from vehicle traffic danger	0.751	
16 I feel safe from intimidation or physical attack	0.681	
<b>Factor 5: Vendor Problems (FA_5)</b>		<b>4.807</b>
17 I think that too many buyers cause this sidewalk crowded	0.881	
18 I think that the number of pedestrians in this sidewalk is too large, causing this sidewalk crowded	0.782	
19 I think that too many street vendors occupy this sidewalk	0.644	
<b>Factor 6: Space Availability (FA_6)</b>		<b>4.13</b>
20 I think that vendor's displays do not obstruct pedestrian movements	0.780	
21 I think that the total width of sidewalk is wide enough	0.686	
22 I can choose my walking speed freely	0.501	
<b>Factor 7: Sidewalk Performance (FA_7)</b>		<b>4.02</b>
23 From my opinion, this sidewalk is bad for pedestrians	0.731	
24 I can not walk side by side with my friend because the sidewalk width is too narrow	0.677	
25 I don't mind delays as long as I am comfortable	0.610	
26 If I want to access public transport, it is easy to find bus stop/BTS Station in this sidewalk	0.508	

Factor 1, labeled 'comfort', comprises seven items and covers 28.94% of the total variance. This factor refers to the existence of obstructions along the sidewalk, such as physical features, vendors and other pedestrian obstructions. Also, sidewalks cleanliness increases comfortable feelings. Factor 2, named 'accessibility', comprises three items and accounts for 12.65% of the total variance. This factor includes items that assess pedestrian perception about easiness to enter/exit the sidewalks, facilities in the crosswalk, and easiness to overtake. Factor 3, labeled 'vendor's attraction', comprises three items and accounts for 7.00% of the total variance. This factor refers to the existence of street vendors along the sidewalks, and pedestrian intention to look around and to buy something on street vendor's commodities. Factor 4, named 'safety/security', includes three items and covers 5.55% of the total variance. This factor includes items that assess pedestrian perceptions regarding vehicle traffic danger, sidewalk surface conditions, and crime attacking. Factor 5, named 'vendor problems', comprises three items and accounts for 4.81% of the total variance. This factor refers to some problems that may arise because of street vendor presence. Factor 6, labeled 'space availability', includes three items and covered 4.13% of the total variance. This factor refers to space availability for walking movement. Factor 7, named 'sidewalk performance', comprises three items and accounts for 4.02% of the total variance. This factor refers to pedestrian opinions about overall performance, delays, and public transport accessibility.

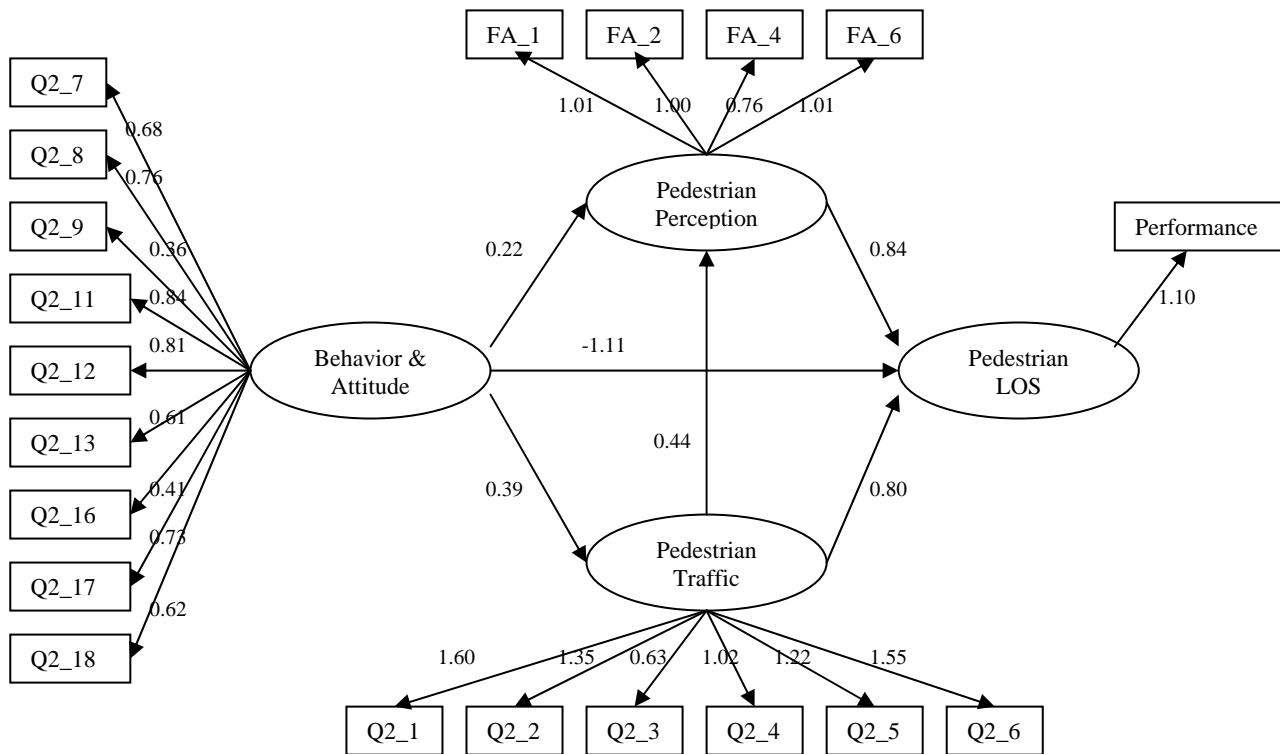
## (2) Structural Equation Modeling Analysis

The proposed model and hypothesized path are tested using the survey data collected. Based on maximum likelihood method of estimation, the AMOS 7 structural equation analysis package is utilized to test the measurement and the structural model<sup>21)</sup>.

Modification indices and standardized residuals suggest that three behavior and attitude items should be eliminated, namely, 'I should walk in the sidewalk although the sidewalk is crowded by vendors' (Q2\_10), 'on street vendors make me easy to buy something' (Q2\_14), and 'I love shopping along sidewalk' (Q2\_15). With the same reason, three of

pedestrian perception items should be removed, namely, ‘vendor attraction’ (FA\_3), ‘vendor problems’ (FA\_5) and ‘sidewalk performance’ (FA\_7). As a result, the remaining items have significant loadings in its construct/latent variable.

Four constructs of interest are used to test the proposed structural model, as seen in Figure 3. By using a correlation matrix among 20 measured variables, SEM analysis is undertaken. SEM results depicted in Figure 3 are  $\chi^2 = 317.3$  ( $p = 0.05$ ),  $df = 145$ ,  $\chi^2/df = 2.188$ ,  $GFI = 0.92$ ,  $AGFI = 0.89$ ,  $NFI = 0.86$ ,  $RMR = 0.17$ , and  $RMSEA = 0.056$ . The results indicate a good fit for the proposed structural model. The model estimation results and the result of testing the hypotheses can be seen in Table 4 and Table 5. These results will be discussed in the following section.



$\chi^2 = 317.3$  ( $p = 0.05$ )  $df = 145$   $\chi^2/df = 2.188$   $GFI = 0.92$   $AGFI = 0.89$   $NFI = 0.86$   $RMR = 0.17$   $RMSEA = 0.056$

Figure 3: Results of testing the hypothetical model

Table 4: Estimation results

Latent Variables	Observed variables	Estimated Parameters	t-stat
Behavior & attitude	Q2_7: It is easy to interact with the vendors	0.68	10.87*
	Q2_8: I want to look around commodities sold by vendors	0.76	11.17*
	Q2_9: Walking slowly to enjoy goods from street vendors is inconvenient for other pedestrians	0.36	4.78*
	Q2_11: I will still walk on the roadway (pavement) even when the sidewalk is very crowded	0.84	9.36*
	Q2_12: In this sidewalk segment, walking on the roadway is more convenient than walking in the sidewalk	0.81	9.34*
	Q2_13: I will walk along this sidewalk only for shopping	0.61	8.97*
	Q2_16: My friends or my relatives like to walk along this sidewalk	0.41	5.70*
	Q2_17: I feel that the government should ban the vendors along the sidewalk	0.73	8.47*
	Q2_18: I think the regulation of vendors along the sidewalk is not that strict	0.62	7.30*
Traffic	Q2_1: I think this sidewalk is crowded because of a large amount of pedestrians, not the presence of vendors	1.60	7.28*
	Q2_2: I think if the vendors is prohibited, the volume of pedestrians will be higher	1.35	6.61*
	Q2_3: I found delay when I walk along this sidewalk	0.63	6.81*
	Q2_4: The street vendors occupy too many spaces in this sidewalk	1.02	6.81*
	Q2_5: I think pedestrians with visual impairment can walk this sidewalk easily	1.22	5.82*
	Q2_6: This sidewalk is too narrow to accommodate the vendors and pedestrians	1.55	6.95*

Table 4: Estimation results (continued)

Latent Variables	Observed variables	Estimated Parameters	t-stat
Perceptions of sidewalk condition	FA_1: Comfort	1.01	14.18*
	FA_2: Accessibility	1.00	13.97*
	FA_4: Safety/Security	0.76	11.13*
	FA_6: Space availability	1.01	15.27*
Level of service	Performance : performance of sidewalk	1.10	11.16*

Note: \*  $p < 0.001$

Table 5: Test results of hypotheses

Hypothesis	Causal path	Estimates	Standard error	t-stat	test result
H <sub>1</sub>	Behavior & attitude → perception	0.22	0.11	2.00*	accepted
H <sub>2</sub>	Behavior & attitude → traffic	0.39	0.05	7.31****	accepted
H <sub>3</sub>	Behavior & attitude → level of service	-1.11	0.29	-3.84***	accepted
H <sub>4</sub>	Traffic → perception	0.44	0.22	2.03**	accepted
H <sub>5</sub>	Traffic → level of service	0.80	0.11	1.99*	accepted
H <sub>6</sub>	Perception → level of service	0.84	0.16	5.33****	accepted

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ , \*\*\*\*  $p < 0.001$

## 5. Discussion and Conclusion

### (1) Discussion

The empirical results indicate that the structural equation model fits relatively well and confirms the research hypotheses. Table 5 shows that pedestrian behavior and attitudes have positive influence on pedestrian perception. Agreed with studies conducted by Zacharias<sup>18)</sup>, once facing sidewalk with many street vendors, pedestrians experience a variety of sensation related to comfort or stimulation. Then, they make a series of judgments and decisions while navigating the environment.

Pedestrian behavior is found to have significantly positive effect on pedestrian traffic. Pedestrian behavior regarding street vendor presence in the sidewalk can be illustrated such as walking slowly to sightseeing or stop to buy something. This is due to the fact that the accumulations of these microscopic behaviors of pedestrians further result in a macroscopic traffic condition.

Surprisingly, the pedestrian behavior was found to be negatively significant on level of service in the model. It can be implied from the findings that most of the respondents were commuters (62.1% daily walking in this sidewalk, 52% go to/from work/school). Therefore, they did not feel comfortable with the presence of vendors in the sidewalk, and overall, it reduces the sidewalk service.

Pedestrian traffic is found to be positively significant on pedestrian perception and pedestrian level of service. Based on references, pedestrian traffic was considered important to level of service<sup>1)-3)-4)</sup>. As indicated in the SEM, improving traffic condition can raise pedestrian perceptions and level of service in the sidewalk.

By SEM analysis, pedestrian perception is found to have positive significance on level of service. In this research, perception refers to the opinion of pedestrian about current sidewalk condition. A better sidewalk condition can lead to better perception that indicates better level of service.

Table 6 presents the direct and indirect effects of latent variables on pedestrian level of service. The results show that pedestrian behavior, traffic, and perception have direct effects on pedestrian level of service. However, pedestrian behavior and traffic have indirect effect on level of service as well.

Table 6: Estimates of direct and indirect effect on pedestrian level of service

Causal path	Effect	Estimates
Pedestrian behavior/attitude → pedestrian LOS	Indirect effect	0.64
	Direct effect	-1.11
	<b>Total effect</b>	<b>-0.47</b>
Pedestrian traffic → pedestrian LOS	Indirect effect	0.37
	Direct effect	0.80
	<b>Total effect</b>	<b>1.17</b>
Pedestrian perception → pedestrian LOS	<b>Direct effect</b>	<b>0.84</b>



The total effect of pedestrian behavior on level of service, which is the sum of indirect and direct effect, is found to be -0.47. The total effect of pedestrian traffic on level of service is found to be 1.17, and the total effect of pedestrian perception on level of service is found to be 0.84. This indicates that the most important factor for pedestrian level of service is pedestrian traffic. This finding agrees with some previous researches that include the pedestrian traffic as one of the variables in the level of service model<sup>1)-3)-4)</sup>.

## (2) Conclusion

This paper has examined a relationship model among pedestrian opinion on behavior and attitudes, pedestrian traffic, pedestrian perception on sidewalk condition and level of service for sidewalk in commercial area. Sidewalk with a large number of street vendors existing is chosen for data collection. From the result in Bangkok, the analysis shows that pedestrian behavior and attitudes have direct influences on pedestrian perceptions, traffic, and level of service. Pedestrian traffic and perceptions are found to have direct effect on pedestrian level of service. Also, pedestrian traffic is found to have direct effect on pedestrian perception. Beside its direct effect, pedestrian behavior/attitude is found to have indirect effect on level of service as moderated by traffic and perception. Also, pedestrian traffic is found to have indirect effect on level of service. Based on the causal effect analysis, pedestrian traffic plays the most important role in affecting a level of service.

The result of this study indicates relationships among some qualitative variables that are considered important for determining pedestrian level of service based on pedestrian opinions. This result can be incorporated with some quantitative variables to establish a pedestrian level of service model. For further research, the pedestrian level of service model including some qualitative and quantitative variables should be investigated. The model could consider on-street vendors' impact as specific characteristics for cases in South East Asian countries.

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### **Investigating Structural Relationships among Pedestrian Perception, Behavior, Traffic, and Level of Service\***

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In this paper, the structural relationships among pedestrian perceptions, behavior, traffic, and level of service are investigated using a structural equation model. Observation was conducted at the sidewalk with vendors activities. The main research results are as follows: pedestrian behavior/attitude has a positive direct effect on perception and traffic, and a negative direct effect on level of service. Pedestrian traffic has a positive direct effect on perception and level of service. Pedestrian perception has a positive direct effect on level of service. Finally, this research indicates that pedestrian traffic is the most important factor for pedestrian level of service.

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