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Heterogeneous Effects of Pedestrian Environments on Walkability by Spatial Cognition Level and Travel Contexts: A Latent Class Ordered Choice Approach

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ABSTRACT

Measuring the pedestrian walkability is extensively emerged in urban planning and transportation area in the last decade, pointing to the walkable city. Previous studies have supposed to calculate the 'Walkability index', in terms of universal walking accessibility based on the walking facilities and street design indices. This approach implied the homogeneous perception of pedestrians, in order to assess the universal walking accessibility upon the road facilities. However, recent studies giving rise to claim that conventional approach is disesteem to the substances of personal contexts, which gained from the preceding experiences or memories of prior walking trips. The present study is position to the progress for heterogeneous perception of pedestrian satisfactions in relation to the contextual factors, such as sociodemographic attributes, spatial cognition level as the location familiarly, and the trip information. This study employing an advanced discrete choice modelling approach to develop the pedestrian walkability Latent Class Ordered Probit Choice model, it facilitates the influence of all the factors and their effects on the heterogeneity in walkability. The analysis results initialise the distinctive responses of walkability in relation to pedestrian latent groups, which can lead the attention to the variability of individual contextual variables. To this end, the paper presents more profound insights of pedestrian walkability, not only indicate the response of pedestrian environments, but also reveal the distinctive preferences on walkability between individuals.

Keywords: Walkability, Pedestrian Contexts, Pedestrian Contextual Groups, Latent Class Ordered Probit Model, Spatial Cognition Level

INTRODUCTION

In recent years, it has increasingly been recognised the 'walkability' research, in terms of measuring the level of pedestrian satisfaction. It becoming a very popular topic for both urban planners and researchers have interested in the sustainable city (1). Previous studies have revealed the significant indicators based upon the (pedestrian) environments factors to measure the walking accessibility (2). Furthermore, empirical studies in US (1, 3–9) mainly complement to calculate the walkability based on the street design (8, 10) and environmental facilities. Overall, these studies paid attention to develop the universal measure of walking accessibility, and also investigate the (dominant) effects of environmental (pedestrian) facilities.

However, previous studies have intend the inherent perceptions, i.e., fixed effects, of pedestrians; (surrounded) environment facilities to account for their walking satisfaction (11, 12). In critique of these conventional studies, this study aiming to audit the heterogenous perception of walkability response to pedestrian environment, in terms of the distinctive perceptions of walking facilities of individuals. In this context, walkability may vary with personal characteristics, such as socio-demographics and spatial cognition levels, and also take into account for the retained perceptions (i.e. random effects), such as prior walking journeys. In addition to their retained perceptions, pedestrians recognised their surroundings while walking, so personal walking experiences, from their routine and habitual daily travels, providing the distinctive perception of walking environments. It supports to investigate a comprehensive set of psychological and environmental factors (2, 13).

To support this extensive perspective, the latest studies (2, 12, 14–17) claiming the shortcoming of conventional researches, in which were supposed to be "one size fits all" (6). These studies also demonstrate the impact of environmental factors on the walkability might be overwhelmed, yet the substances of individual characteristics and contextual factors are disesteemed. For instance, Lee et al. (2) estimated the walkability indicators using discrete choice modelling approach, to exhibit the personal experience and contexts are dominant factor to influence on walkability than walking facilities and land-use indices. Building on this foundation, Erath et al. (17) developed a software tool that integrates the results from behaviour surveys with network-based walking facility datasets, to compute the walkability index incorporate with user preferences. Additionally, these studies also addressed the heterogeneous effects on walkability, which generated by the difference in individual trip characteristics: utilitarian and recreation trips (2, 13, 19) and fixed and flexible trip purpose (12), respectively.

In overview, this study supports the alternative approach, not only demonstrate the level of pedestrian satisfaction, but also examine the heterogenous perception to walking facilities by pedestrian contextual variables. To achieve this task that the research examines the distinctive influence of pedestrian environments on walkability coupling with the pedestrian contexts, in regard to their previous travel experiences; for instance, sociodemographic attributes, spatial cognition level as the location familiarly, and the trip characteristics. Additionally, external conditional attributes such as weather conditions and crowdedness, in terms of relative excessive population volumes in relative to average pedestrian volumes at each survey location by the course of the day, are also considered as kind of contextual factors. To simultaneously consider all the factors and their effects on the heterogeneity in individual walkability, an advanced discrete choice modelling approach (i.e., Latent Class Ordered Probit Choice model) is employed. This approach is allowing to provide more profound insights into the relationship between pedestrian environments, not only identifying the heterogeneous responses on pedestrian walkability, which simultaneously estimating why people feel differently (i.e. the contextual effects), but also interrogating what extent they feel differently with respect to the pedestrian walkability. Therefore, empirical results using this approach could be deliver the viable insight to urban planners, who aim to establish walkable cities with enhanced urban streets for everyone with resulting from a better understanding of walkable pedestrian environment design criteria. In the present study, the model was estimated based on 83,291 responses of 'Seoul Pedestrian Survey' administered in November 2009 in Seoul, Korea.

This paper is structured in the following manner. In the next section, the data deployed in this research is described, it provides the details of data resources; the survey information and explanatory variables. In section three, the analytical strategy of the research is present the deployed approach, i.e., the Latent Class-Ordered Probit Model. The model estimation results are presented and described at the section four. Finally, we discuss the empirical summarises of the research findings.

DATA USED

The 'Seoul Pedestrian Survey' was conducted in the whole Seoul area from September to November in 2009. There were two stages in the survey data collection; on one hand an interview was taken from respondents, on the other hand various pedestrian environemtal charteristics were investigated and recorded, such as pedestrian flow (in volumes per hour), walking road width, obsticles, pedestrian-support facilities (e.g., fence), and so forth. At each survey location, surveyors collected responses from 24 pedestrians on Tuesdays, Wednesdays, and Fridays, yielding 72 responses per location. Up to 2,400 individuals per day were interviewed (Seoul Metro Government, 2010). The questionnaire collected the pedestrian walkability, the pedestrian's activity−travel, and personal information. There were over 1,170 survey locations, totalling 83,291 responses (Lee et al., 2018, page 1).

Based on the extensive dataset, we selected important variables and manipulated some of them to represent pedestrian environment and pedestrian contexts. **Table 1** presents the variables used for this study. First, the pedestrian walkability is considered which was measured by 3 ordinal scales: uncomfortable, neutral, and comfortable. The survey asked the respondents to indicate how much they feel comfortable to walk through the survey area. In addition, the respondents were asked to provide some information regarding pedestrian contexts such as socio-demographics, familiarity of the area, and trip characteristics. There are two variables to represent the familiarity of the area: residential location (whether or not the location is in the same administriative district with the survey location), and vsiting frequency of the area. The familiarity of the area is employed to measure the spatial cognitive level of each respondent. We assume that people who live close to the survey location and/or visit the location very frequently tend to be familiar with the area, and thus that they have a higher level of spatial cognition with respect to the area. Two variables were selected to represent the trip charactecrics of each respondent: trip purpose and travel companion (whether to walk with others or not).

TABLE 1 Variable Lists with Descriptive Infromation of the Sample

Variable			**Data Type**	**Attrubutes**	**Sample Distribution**
Pedestrian walkability			Ordinal	Uncomfortable Neutral Comforable	40.1% 41.9% 18.0%
Pedestrian contexts	Socio-demographics	Gender	Nominal	Male Female	44.6% 55.4%
		Age	Ordinal	Teenager (Ages 15-19) Adults (Ages 20-59) Elderly (Ages over 60)	7.0% 79.3% 13.7%
	Familiarity	Residence in the same administrative district with the survey location	Nominal	Yes (Dweller) No (Stranger)	54.3% 45.7%
		Visiting frequency	Ordinal	Every day 3−5 days/weak 1-2 days/week Rarely (1-3 days for 6 months and first visit)	40.4% 31.2% 14.2% 14.2%
	Trip characteristics	Trip purpose	Nominal	Utilitarian Others	42.9% 57.1%
		Travel companion	Nominal	With others Alone	73.0% 27.0%
Pedestrian environments	Facility characteristics	Walking road width	Ratio	Meter	mean: 4.17 std.: 2.278
		Presence of central lines	Nominal	Yes No	61.5% 38.5%
		Number of total road lanes	Ratio	Lanes	mean: 3.47 std.: 2.64
		Presence of walking obstacles	Norminal	Yes No	94.2% 5.8%
		Mixed traffic street	Nominal	Yes No (Pedestrian only or with bike)	29.8% 70.2%
		Presence of sidewalk fence	Nominal	Yes No	19.2% 80.8%
		Presence of crossings	Nominal	Yes No	57.1% 42.9%
		Presence of public transit stations within 50m	Nominal	Bus and subway Bus or subway Nothing	7.8% 31.6% 60.6%
	Survey ponts characteristics	Crowdedness (Time−based)	Continuous	1 = average	mean: 0.993 std.: 0.374
		Type of spot	Nominal	Main road Residential area Others	14.1% 17.9% 68.0%
		Land-use mix	Continuous	Continuous	mean: 0.93 std.: 0.03

Variables representing the conditions of pedestrian environments can be classified into the facility characteristics and the survey point's characteristics. The pedestrian facilities have gathered during the survey periods to report the capability of pedestrian facilities, which encompassing the surrounding area (within 50m ranges) of each survey points. In other words, the pedestrian facilities depict the multitude typology of survey spots incorporate with the adjacent arterial road attributes. There are three kinds of environmental facilities, which describing the amenity level of pedestrian facilities as follows: 1) The constitutional survey spot facilities, such as the walking road width, and mixed traffic street. 2) The characteristics of adjacency roads, it comprising the number of total road lanes, and the installation of safeguard amenities for pedestrians: sidewalk fence, crossings, and walking obstacles. Additionally, in terms of walking obstacle that retraining the inconvenience of walking experiences to pedestrians, such as street trees, distribution transformer, street lights, and so forth. Finally, 3) convenience to the public transits (i.e. accessibility within 50m).

Subsequently, the land use information of each survey points are also take into account for illustrating the typology of survey spots and adjacent arterial road areas. Crowdedness was measured by the periodic levels of pedestrian volumes in contrast to the average daily pedestrian volumes at each survey spots. As described in Lee et al (2), the pedestrian volumes may lead to establish the impression of the area, and further pedestrians may be obtained the walkability scores whereas retained by their walking experience. To account for this, the time-sensitive crowdedness index was employed to take account for the variation of pedestrian volumes by four periods per day at each survey points, if the value is equal to 1, it represents the sporadic pedestrian volume is equal to the average volume. A value lower or higher than one indicates, reprehensively, a lower or higher than usual volume.

METHODOLOGY

This study employs a latent class choice approach. The underlying theory of the latent class choice approach assumes that a number of classes exists within the population, and that preferences of the individuals involved in a class tend to be homogeneous, but each of classes has different preferences. However, which class contains any particular individual is unknown to the analyst. The approach estimates simultaneously the probability that an individual is included in each latent class and the probability that the individual chooses a certain alternative across different classes (24). This approach is generally accepted in many transportation studies in order to investigate heterogeneity in travel behaviour. Application domains include, for instance, household location decisions (25), route choice behaviour of truck drivers (26), bicycle parking preferences of train travellers (27), preference of alternative-fuel vehicles (28), and departure time choice of train commuters (29).

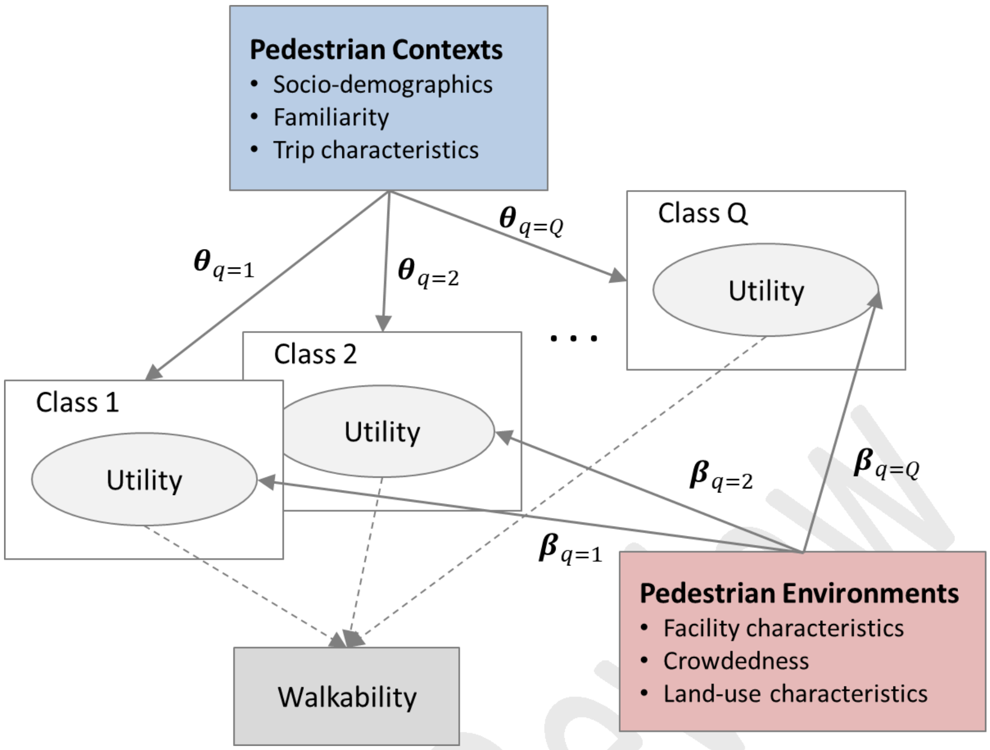

Figure 1. Latent Class Order Probit Model framework.

In this study, a latent class ordered probit model is developed to account for the ordinal nature of the dependent variable (i.e. pedestrian walkability) and the heterogeneous effects of attributes (i.e. pedestrian environments) on the dependent variable. **Figure 1** depicts the model framework of this study. We assume that the level of pedestrian walkability indicated by an individual is associated with the utility of the individual stemming from the pedestrian environments (i.e. facility characteristics, crowdedness, and land-use characteristics) and that the utility varies according to the pedestrian contexts with respect to the individual (i.e. socio-demographics, familiarity, and trip characteristics). Based on this, the probability that individual n indicates jth ordinal value for the walkability of pedestrian passage l can be formulated as follows:

$$P_{nl}(j) = \sum_{q \in Q} H_n(q) P_{nl}(j|q) \tag{1}$$

where $H_n(q)$ is the probability that individual n involves in pedestrian-context class q, which is called as the class membership probability. The latent class modelling approaches generally suggest estimating the probability based on the formulation of the multinomial logit model as follows:

$$H_n(q) = \frac{\exp(\boldsymbol{\theta}_q \boldsymbol{Z}_n)}{\sum_{g \in Q} \exp(\boldsymbol{\theta}_g \boldsymbol{Z}_n)} \tag{2}$$

where $\boldsymbol{Z}_n$ indicates a $(M \times 1)$ vector of the pedestrian context variables with respect to individual n, and $\boldsymbol{\theta}_q$ is a $(1 \times M)$ vector of parameters corresponding to pedestrian-context class q.

In equation (1), $P_{nl}(j|q)$ is the conditional probability that individual n indicates jth ordinal value for the walkability of pedestrian passage l in the context of class q. We employed a system of ordered probit model for representing individual's decision-making process regarding ordinal scale of the walkability as follows:

$$U_{lnq} = \boldsymbol{\beta}_q \boldsymbol{X}_{ln} + \varepsilon_{lnq}, \tag{3}$$

$$y_{ln} = \begin{cases} 1, & \mu_{q,0} < U_{lnq} < \mu_{q,1} \\ 2, & \mu_{q,1} < U_{lnq} < \mu_{q,2} \\ & \cdots \\ j, & \mu_{q,j-1} < U_{lnq} < \mu_{q,j} \\ & \cdots \\ J, & \mu_{q,J-1} < U_{lnq} < \mu_{q,J} \end{cases} \tag{4}$$

where U_{lnq} is the utility of individual n with respect to pedestrian passage l in the context of class q, which consists of the systematic utility $\boldsymbol{\beta}_q \boldsymbol{X}_{ln}$ and the random disturbance ε_{lnq}. $\boldsymbol{X}_{ln}$ indicates a $(K \times 1)$ vector of the pedestrian environment variables with respect to pedestrian passage l, and $\boldsymbol{\beta}_q$ is a $(1 \times K)$ vector of parameters representing the effects of the pedestrian environment variables on the utility which varies according to pedestrian-context class q. y_{ln} means an ordinal value for the walkability indicated by individual n with respect to pedestrian passage l. According to equation (4), the model assumes that individual n indicates the jth ordinal value for the walkability if the utility U_{lnq} lies within a particular range between $\mu_{q,j-1}$ and $\mu_{q,j}$. The cut-off parameters $\boldsymbol{\mu}_q = (\mu_{q,0}, \cdots, \mu_{q,J})$ for each pedestrian-context class should be estimated. By assuming the probability density of the random disturbance ε_{lnq} as the normal distribution, the choice probability $P_{nl}(j|q)$ can be expressed as follows:

$$P_{nl}(j|q) = \boldsymbol{\phi}(\mu_{q,j} - \boldsymbol{\beta}_q \boldsymbol{X}_{nl}) - \boldsymbol{\phi}(\mu_{q,j-1} - \boldsymbol{\beta}_q \boldsymbol{X}_{nl}) \tag{5}$$

where $\boldsymbol{\phi}(\cdot)$ represents the cumulative density function of the standard normal distribution.

To estimate the unknow parameters, the maximum likelihood method is employed in the present study. All the parameters associated with the class membership and the choice probability functions are estimated simultaneously. On the other hand, the optimal number of latent classes (Q) cannot be estimated simultaneously. Typically, the optimal number of classes is chosen based on a comparison of the model fit of a series of models with different number of classes. To measure and compare model fit, the present study employs Akaike information criterion (AIC) and Bayesian information criterion (BIC). In the both criteria, a lower value indicates a better goodness-of-fit.

ANALYSIS RESULTS

To identify the optimal number of latent classes, a series of models were estimated. Error! Reference source not found. presents the model fit of the one-, two-, three-, and four-latent class models. The value of both AIC and BIC continues to decrease as the number of class increase indicating that more latent classes result in a better fit. Considering the model fit and the interpretability of classes, we have selected the four-class model as the optimal model for investigating the heterogeneous effects of pedestrian environments on walkability. Error! Reference source not found. provides the estimation results of the one-class model (Model 1) and the four-class model (Model 2).

TABLE 2. Model Fit for the 1 to 4 Latent Class Membership Model.

Number of classes	1	2	3	4
Number of parameters	15	40	65	90
Log-likelihood value	-84461.85	-84087.20	-83750.57	-83125.56
AIC	168953.69	168254.40	167631.15	166431.12
BIC	169093.45	168627.08	168236.75	167269.65

Model 1 presents the effects of the pedestrian environments on the walkability that are assumed to be homogeneous across different pedestrians. According to the estimation results, people tend to feel more walkable for a wider passage, and most of walking facilities tend to represent a positive response. In contrast to common safety considerations, the existence of central-line and mixed streets types exhibited a negative influence on the pedestrian satisfaction. Subsequently, pedestrians perceived a place more walkable when the area was characterised by a diversity of zoning types, yet too much crowding is experienced negatively as shown by the estimated coefficients. Furthermore, the residence indicator was also selected as a significant variable to influence the pedestrian walkability. In particular, the Seoul inhabitants, who hold an extensive spatial cognition of their routinely visited areas, "perceived distress". The visiting frequency are used to unique define a routine visitor (i.e. every day and 3-5 days/week visitors).

Before moving on to the Latent Class Ordered Probit model (Model 2) estimation results, the methodological approach of this study is as follows: the Latent class framework was applied in this study. The Latent class framework indicated that relatively few classes are sufficiently flexible to capture quite complex patterns of heterogeneity (30). In this context, Latent class choice models are appropriate to distinguishing particular classes under the assumption that individuals' preferences in the same classes (i.e. membership groups) are homogeneous (25, 26).

From the estimation results of both Model 1 and 2, the distinctive correlation patterns of pedestrian environments on walkability were estimated. As stated before, the walking facilities, particularly the presence of fences, crossings, and trees as obstructions, were found having a positive influence. However, vehicle-oriented facilities were discovered to have negative effects on walkability.

Furthermore, the indicator of crowdedness of the street was estimated to have a negative influence. A mixed land-use index represents positive effects on walkability. The estimated results show that accessibility, which comprises the accessible distance for walking, generally positively contributes to pedestrian satisfaction levels (10) However, the crowdedness, the density of pedestrians, may lead to a negative influence on walkability (31). In this context, the pedestrian profiles may become the decisive factors to assess the pedestrian satisfaction level. Individual contextual attributes thus lead to distinctive responses in the choice of walkability as demonstrated by the Model 2 estimation results. In particular, it was discovered that dwellers (both in Seoul and Metropolitan area) tend to be more sensitive for responding the negative walkability than visitors. This may be explained by the spatial cognition and the density of residence in particular.

Model 2, latent class ordered probit model, first the four classes (the optimal number of latent membership groups according to the model estimation results using NLogit 4 software) were estimated. The profiles of latent classes were investigated, as it is the evidence shows that the characteristics of respondents are not only influenced by the choice of walkability, but also by the preferences of each class (being characterized by distinctive conditions and contexts). In other words, this study contribute to the development of latent class choice approach in walkability model, not only to distinguish the significant factors, but also explore the psychological indicators and preserved contexts for testing the stated preference experiments. The latent class modelling is deployed as an appropriate technique to detect the heterogeneous preferences in the contextual variables, according to the theoretical review. In the next section, each latent classes is explored, and distinct responses to their choices of (pedestrian) satisfaction are discovered in relation to pedestrian context membership groups.

Class 1: Male 'Walk-holic' adults, who lived in the metropolitan area, outside of Seoul.

Class 2: 'Female Seoul inhabitants', who generally walking together with companion

Class 3: 'Female Seoul commuters', who usually walking together with companion

Class 4: Male 'Saunters', who dwelled in metropolitan area

This section describes the relationship between pedestrian environments and classes; that is the heterogeneous responses (coefficients) of each pedestrian context group to pedestrian environments from the estimation results (see Error! Reference source not found.).

Group 1 around a quarter (23.9%) of pedestrians belongs to this class. It is termed as 'walk-holic' male adults. This group has a very strong base dependence on land-use variables, such as the mixed land-use index and road types, especially in main-road survey spots. It can be interpreted as the local facilities may cause to the significant indicator to determine the preference of pedestrian walkability of Group 1.

Contradicting previous claim of Group 2 and group 3 are seems to be very similar classes, which being predominantly populated with Seoul female dwellers. Yet their trip purpose is distinctive, i.e. either walking commuters (i.e. utilitarian walking) or walkers for their discretionary travel purpose. Group 2 seems to be unique latent class in pedestrians because their response to pedestrian environments dramatically differs from overall tendency (i.e. the estimation results of Model 2). The female Seoul dwellers seem to be much stressed from crowdedness during walking, nor mixed land-use index which to be taken place the much volume of pedestrians in the walking street. In this sense, each latent membership group has a distinctive spatial cognition level depending on the locations. In particular, the locals who retained the knowledge of spatial recognition stated a positive satisfaction level for their walking experiences. Furthermore, they reacted also positively to accessible public transportation facilities, for which they have stronger preferences than any other classes.

Moreover, Group 3 mainly comprises the 'Seoul female commuters', who prefer walking together with someone for their commuting. As we discussed before, groups 2 and 3 have similar profiles of each group members, however their response for pedestrian environments are not identical. In other words, utilitarian pedestrian groups have a more negative influence than other travel purposes. Group 3 shows this difference more clearly. The membership groups have a negative effect from accessible public transportation facilities, yet they are positive at main roads survey spots and crowded walking streets. This preference can be interpreted in relation to their habitual and routine walking experiences which were accumulated during their previous commuting walking trips. Both subway gates and bus stops in Seoul are crowded during the peak hours, as well as the main-streets, which are consistently a high dense area for moving pedestrians during the daytime.

Finally, Group 4, which is the largest class (28.7%), represents a large number of local metropolitan males who prefer to walk alone. It has a marginally different response compared to the overall tendency, especially for the width of walking street, mixed road types, and crossings. However, it may lead to investigate the importance of trip purpose, which caused the distinctive pedestrian walkability choice.

In summary, we identified the effects of pedestrian contexts on walkability in the estimation results of Model 2, and compared it with Model 1. The most important indicators were identified from the estimation results: trip purpose and spatial cognition, and gender. In addition, the estimation results for Model 2 revealed the coefficients among the pedestrian environmental factors on walkability, which influence the pedestrian walkability between discrete membership groups by pedestrian contexts.

To be specific, 'Female Seoul dwellers', as membership group 2 in Model 2, yields the most heterogeneous response on the pedestrian environments compared to other groups, which is in contrast to the Model 1 estimation results. Additionally, the gender information is a substantial indicator for the discrete latent classes: Males (Group 1 and 4) and Females (Group 2 and 3). Each gender group shares some common characteristics regarding their pedestrian contexts; however, they have distinctive choice preferences regarding the pedestrian environments, in relation to walkability.

As indicated previously, the analysis results stem from the participants' historical experiences of walking and their spatial knowledge. As far as walkability is concerned, the psychological conditions and acknowledged experiences of pedestrians in respect to their routine walking behaviour may produce distinctive (individual) stated preferences for their walkability choices. From the extensive findings of this analysis, it was discovered that the walking-trip purposes and survey spots associated with the accumulated spatial cognition are substantial indicators to establish the perceived preference of each membership group.

TABLE 3. Model Estimation Results

Model Component	Attributes		Model 1 (The one-clase model)			Model 2 (The four-class model)											
						Class 1 (23.9%)			Class 2 (20.3%)			Class 3 (27.1%)			Class 4 (28.7%)		
			B	**Std.**	**Z.**	**B**	**Std.**	**Z.**	**B**	**Std.**	**Z.**	**B**	**Std.**	**Z.**	**B**	**Std.**	**Z.**
Pedestrian walkability choice part	Constants		**0.5132**	0.0215	23.92	**1.0480**	0.1901	5.51	**-0.9515**	0.2005	-4.75	**0.8316**	0.1495	5.56	**1.4007**	0.1638	8.55
	Walking road width		**0.0214**	0.0020	10.97	**0.0500**	0.0172	2.90	**0.3694**	0.0259	14.25	**-0.0408**	0.0121	-3.37	**-0.0467**	0.0128	-3.67
	Presence of central lines		**-0.1168**	0.0068	-17.24	**-0.4493**	0.0679	-6.62	**0.6340**	0.0863	7.35	**-0.1487**	0.0439	-3.38	**-0.4222**	0.0562	-7.51
	Number of total road lands		**0.0557**	0.0023	24.76	**-0.0807**	0.0256	-3.16	**0.2708**	0.0248	10.94	**-0.1074**	0.0201	-5.33	**0.2396**	0.0270	8.88
	Presence of walking obstacles		**0.0375**	0.0085	4.44	**0.4340**	0.0655	6.63	**-0.6596**	0.0887	-7.44	**0.2167**	0.0508	4.26	-0.0819	0.0517	-1.59
	Mixed traffic street		**-0.0695**	0.0067	-10.32	**-0.7072**	0.0797	-8.87	-0.0095	0.0671	-0.14	0.0421	0.0396	1.06	**0.0944**	0.0482	1.96
	Presence of sidewalk fence		**0.0147**	0.0054	2.73	0.0553	0.0507	1.09	**-0.3339**	0.0473	-7.05	**0.1384**	0.0301	4.59	**0.0766**	0.0339	2.26
	Presence of crossings		**0.0249**	0.0050	5.01	**0.2826**	0.0508	5.57	**0.5210**	0.0530	9.84	**-0.0924**	0.0321	-2.88	**-0.2147**	0.0412	-5.21
	Presence of stations in 50m	Bus and Subway	**-0.0410**	0.0104	-3.95	0.0161	0.0865	0.19	**0.5539**	0.1057	5.24	**-0.3016**	0.0481	-6.27	**-0.2408**	0.0632	-3.81
		Bus or Subway	**0.0282**	0.0071	4.00	**-0.2511**	0.0665	-3.78	**-0.2464**	0.0668	-3.69	**0.2974**	0.0414	7.19	**0.1080**	0.0453	2.38
		Nothing	0.0128	-	-	0.2350	-	-	-0.3075	-	-	0.0042	-	-	0.1328	-	-
	Crowdedness (Time-based)		**-0.1149**	0.0106	-10.86	**-0.4778**	0.0915	-5.22	**-0.7274**	0.1014	-7.18	**0.3057**	0.0656	4.66	**-0.1569**	0.0669	-2.35
	Land-use mix		**0.3001**	0.0164	18.30	**1.1412**	0.1521	7.50	-0.2289	0.1465	-1.56	**0.3525**	0.0984	3.58	0.0414	0.0995	0.42
	Type of spot	Main road	-0.0046	0.0083	-0.55	**0.3715**	0.0787	4.72	**-1.4633**	0.1106	-13.23	**0.6160**	0.0711	8.66	-0.0654	0.0656	-1.00
		Residential area	**-0.0395**	0.0082	-4.84	**-0.8551**	0.0856	-9.99	**2.3654**	0.1577	15.00	**-1.1001**	0.1034	-10.63	**0.1934**	0.0886	2.18
		Others	0.0441	-	-	0.4836	-	-	-0.9022	-	-	0.4841	-	-	-0.1279	-	-
Pedestrian – context class membership part	Constants		-	-	-	**-0.3087**	0.1466	-2.11	**-0.3938**	0.1213	-3.25	-0.1690	0.2202	-0.77	-	-	-
	Gender	Male	-	-	-	**-0.0950**	0.0265	-3.58	**-0.1412**	0.0276	-5.11	**-0.1851**	0.0398	-4.65	-	-	-
		Female	-	-	-	0.0950	-	-	0.1412	-	-	0.1851	-	-	-	-	-
	Age	Teenager	-	-	-	**-0.6353**	0.0742	-8.56	**-0.5595**	0.0733	-7.63	**-0.7312**	0.1110	-6.59	-	-	-
		Adults	-	-	-	**0.1108**	0.0412	2.69	0.0210	0.0422	0.50	**0.2237**	0.0696	3.22	-	-	-
		Elderly	-	-	-	0.5245	-	-	0.5385	-	-	0.5076	-	-	-	-	-
	Region	Dweller	-	-	-	**-0.2525**	0.0327	-7.72	**0.1339**	0.0283	4.74	**0.1483**	0.0436	3.40	-	-	-
		Stranger	-	-	-	0.2525	-	-	-0.1339	-	-	-0.1483	-	-	-	-	-
	Visiting frequency	Every day	-	-	-	**0.1698**	0.0462	3.67	**0.3779**	0.0480	7.88	**0.3077**	0.0662	4.65	-	-	-
		3-5 days/week	-	-	-	0.0701	0.0454	1.54	**-0.1132**	0.0453	-2.50	**-0.3393**	0.0692	-4.90	-	-	-
		1-2 days/week	-	-	-	**-0.1162**	0.0511	-2.27	**-0.1804**	0.0533	-3.38	**-0.1368**	0.0829	-1.65	-	-	-
		Rarely	-	-	-	-0.1238	-	-	-0.0843	-	-	0.1684	-	-	-	-	-
	Trip purpose	Utilitarian	-	-	-	**0.0444**	0.0270	1.65	**0.0606**	0.0279	2.17	**0.1199**	0.0427	2.81	-	-	-
		Others	-	-	-	-0.0444	-	-	-0.0606	-	-	-0.1199	-	-	-	-	-
	Travel companion	Alone	-	-	-	**-0.0644**	0.0354	-1.82	**-0.2203**	0.0353	-6.23	**-0.2698**	0.0465	-5.81	-	-	-
		With someone	-	-	-	0.0644	-	-	0.2203	-	-	0.2698	-	-	-	-	-

Note: Estimates whose p-values are less than 0.05 are marked in bold.

CONCLUSION

With respect to the comparison between discrete choice model estimation results, a substantial influence of pedestrian contexts on walkability was observed, which not only accounts for the perceived preferences, but also produces the discrete membership groups in terms of latent classes.

The estimation results of Latent Class Ordered Probit model, provided evidence for the distinctive responses (i.e. diverse coefficients values) of walkability choices, in relation to individuals' contextual characteristics. These findings using a Latent class ordered-probit model indicated the significant influence of pedestrian contexts, which can lead to the perceived pedestrian walkability. Furthermore, the analysis results of this study support that perceived experiences and memories of individual groups may influence the walkability choices.

Moving on to the individual variability, i.e., pedestrian contextual attributes, such as spatial cognition level and trip characteristics; these were shown to behave as the most significant indicators, more than the pedestrian environments (especially facilities on the walking road), which is the fruitful information for urban planners and decision makers.

Finally, this study also initialises and updates the knowledge of the relationship between pedestrian environments and their perceived walkability with respect to personal contextual variables. It thus provides valuable information to urban planners and decision makers to update their best knowledge so they could design better walkable pedestrian environments, not only concerning the residential inhabitants, but also respect the time-specific visitors, i.e. visiting populations.

Although the contributions of this study, i.e. the influence of environmental factors on walkability, and the significantly distinctive response in relation to the pedestrian (behavioural) contexts, are considerable, this study is also limited to appraise how much the heterogeneous individual contexts affects pedestrian walkability. This challenge may be addressed in futures studies, which could employ advanced discrete choice modelling approaches.

In summary, future studies on the current topic, that is to investigate the external contextual attributes associated with daily activity-travel patterns, are recommended. For instance, weather conditions and the crowdedness by periods of day in a given area may generate distinctive choices of walkability according to the individuals' routine activities.

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