

Waiting for signalized crossing or walking to footbridge/underpass? Examining the effect of weather using stated choice experiment with panel mixed random regret minimization approach

ABSTRACT

It is a challenging task for pedestrians to cross a road with multiple traffic lanes and busy traffic. Many footbridges and underpasses have been built in the urban area of metropolitan cities such as Hong Kong to resolve the problem of vehicle-pedestrian conflict. To maximize the utilization and benefit of the installation of such crossing facilities, it is crucial to understand the choice behaviour of pedestrians. Although many studies have examined pedestrian walking behaviour and preference towards crossing facilities, the influence of ratio of perceived values between waiting and walking time on the choice of crossing is not explored. In addition, individual perception and choice may vary with the environmental conditions, which has not been fully accounted for in existing studies. Exposure to extremely hot weather, crowded walkways, and roadside traffic emissions are not favoured. In this study, a stated choice experiment is developed to examine the relationship between possible influencing factors and the crossing choices of pedestrians in Hong Kong. In addition, a regret-based panel mixed multinomial logit approach is adopted to model the choice, accounting for the effects of unobserved heterogeneity and panel data. The results indicate that the choice decision of pedestrians is more sensitive to an increase in waiting time at signalized crossings than to an increase in walking time to access footbridges and underpasses. These findings shed light on future urban and transport planning strategies to improve the walking environment and promote walkability.

Keywords: Pedestrian crossing facilities; Perceived value of time; Urban environment; Stated choice experiment; Panel mixed multinomial logit model; Regret minimization approach

1. INTRODUCTION

1.1. Background

Walkability is increasingly popular in urban and transport planning because walking can reduce traffic emissions, relieve traffic congestion, improve physical health, and support the well-being of society (Pucher and Buehler, 2010; Lawlor et al., 2003; Lo, 2009; Elias and Shiftan, 2012). This is particularly true for transit-oriented cities such as Hong Kong, where 89% of trips are made by public transportation and walking is the primary means of access (Hong Kong Transport Department, 2014; Li and Loo, 2016; Sze et al., 2019).

Safety is a key attribute of walkability. To resolve pedestrian-vehicle conflicts and improve traffic safety at intersections and crosswalks, different pedestrian facilities have been installed to separate pedestrian and vehicular traffic by either time (signalized crossings) or space (footbridges and underpasses) (World Health Organization, 2018; Rankavat and Tiwari, 2020; Zhu et al., 2021a). However, these approaches may also suffer from shortcomings. For example, traffic signals increase the waiting time of pedestrians and vehicles and worsen traffic congestion (Vandaele et al., 2000). In contrast, the construction and maintenance costs of footbridges and underpasses are much higher than those of signalized crossings (Yip et al., 2014). Additionally, pedestrians may struggle with the use of footbridges and underpasses because of extra walking distance, climbing up or down stairs, poor lighting and hygiene, and security concerns (Sharples and Fletcher, 2001; Sinclair and Zuidgeest, 2016; Zhu et al., 2021b). One study indicated that females and elderly individuals were hesitant to use footbridges and underpasses, especially at night (Rankavat and Tiwari, 2016). Hence, it is crucial to identify the factors that affect pedestrians' perception and choice among different crossing facilities for the design and planning of transport infrastructure. In particular, the trade-off between additional waiting time at a traffic signal and effort to access footbridges and underpasses should be considered (Rankavat and Tiwari, 2020; Chowdhury and Van, 2020).

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2 Many developed societies are facing the problem of an ageing population. In the United Kingdom,
3 the proportion of the population above 65 years of age doubled in 15 years (Hanson, 2004). In
4 Hong Kong, the proportion of older inhabitants is expected to increase from 12% in 2015 to 25%
5 in 2035 (Hong Kong Legislative Council, 2015). Hence, there has been increasing concern for
6 universal access in building design and urban development in recent years. For instance, it is
7 necessary to consider the needs of individuals with limited mobility for access to different public
8 facilities, such as underground stations, footbridges and underpasses, and elevated walkways (Sze
9 and Christensen, 2017; Xu et al., 2022; Yi and Ling, 2020). In Hong Kong, many footbridges and
10 underpasses were built more than 40 years ago. To enhance the accessibility to footbridges and
11 underpasses for all, facilities such as ramped walkways, elevators, and people-movers have been
12 installed in recent years (Hong Kong Building Department, 2011; Hong Kong Highway
13 Department, 2020). Furthermore, weather conditions can also affect pedestrians' perception and
14 walking experience. Summer in Hong Kong is hot and humid because of the subtropical climate,
15 and the average annual precipitation is over 2,300 mm. In 2020 and 2021, 55 "very hot weather
16 warnings" and 78 "rainstorm warning signals" were issued (Hong Kong Observatory, 2022). Thus,
17 the effects of extremely hot weather and rainy conditions on the choice decisions of pedestrians
18 must be considered.

19 20 **1.2. Literature gap**

21 Data collection methods including self-report questionnaires (Cambon et al., 2009; Dommes et al.,
22 2015), video observation surveys (Diependaele, 2019; Zhu et al., 2021b), computer vision and
23 automated tracking (Papadimitriou, 2012), simulated experiments (Calvi et al., 2020), global
24 positioning systems (Lassarre et al., 2012), and revealed preference surveys (Arellana et al., 2022)
25 have been adopted to examine the walking behaviour of pedestrians. Moreover, factors including
26 road design, walking environment, and traffic conditions that affect pedestrian route choices have
27 been identified (Garrod et al., 2002; Perdomo et al., 2014; Beitel et al., 2018). A few studies have

1 examined the factors that affect pedestrians' preference and tendency to use different crossing
2 facilities. In particular, one study has considered the effects of pedestrian gender and age on the
3 choice of crossing facilities (Anciaes and Jones, 2018). On the other hand, two recent studies have
4 explored the effect of pedestrian occupation on the choice of grade-separated crossing facilities.
5 Results indicated that working professionals had higher tendency to use footbridge, compared to
6 students (Chandrappa et al., 2021; Bhatia et al., 2022). However, it is rare that other socio-
7 economic characteristics like personal income and education level are considered for the choice of
8 crossing facilities. Furthermore, interaction effect of weather conditions on the relationship
9 between personal characteristics and choice of pedestrians should be accounted.

10
11 To examine individuals' preferences in hypothetical settings, the stated preference (SP) approach
12 has been applied to study transport mode choice (Jin et al., 2020), perception of community
13 severance (Anciaes et al., 2018), walking path choice (Anciaes and Jones, 2020), electric vehicle
14 ownership (Jia and Chen, 2021), and traffic enforcement (Li et al., 2014; Steinbakk et al., 2019).
15 With the use of SP approach, it is possible to measure the pedestrians' willingness to "pay" for the
16 use of specified crossing facilities (Anciaes and Jones, 2018). However, difference in the perceived
17 values between walking time and waiting time was rarely considered. Furthermore, moderating
18 effect of environmental conditions on the association between waiting time, walking time, and
19 pedestrian choice behaviour is yet to be explored.

20
21 For the analysis method, random utility maximization (RUM) approach is usually adopted in
22 conventional discrete outcome models for pedestrian choice behaviour (Anciaes et al., 2018;
23 Anciaes and Jones, 2018; Beitel et al., 2018). The RUM approach assumes that individuals favour
24 the choice that provides the highest level of satisfaction (Train, 2009). However, bias in parameter
25 estimation is possible since the RUM approach allows for self-compensation between
26 underperforming and outperforming attributes (Chorus et al., 2008). Therefore, an alternate
27 approach, random regret minimization (RRM), should be considered. The advantages of RRM are

threefold. First, RRM considers the attributes of both selected and unselected options in the estimation: a choice that has less regret is preferred. In addition, RRM can improve the model fit. Furthermore, the constant assumption for willingness-to-pay estimates (i.e., trade-offs between attributes) can be relaxed when RRM is adopted (Zhu et al., 2021a; Iraganaboina et al., 2021).

1.3. Objectives

In this study, the roles of facility design and planning, environmental conditions, and personal characteristics in pedestrian choice among signalized crossings, footbridges, and underpasses are examined using a stated choice experiment. For example, hypothetical scenarios for different combinations of geometric design, crowdedness, accessible design (i.e., elevators, stairs, ramped walkways), traffic flow, and weather conditions are visualized (; Mukherjee and Mitra, 2020; Zhu and Sze, 2021). In addition, personal characteristics, including socio-demographics, walking habits, and the self-rated importance of the design attributes of crossing facilities are considered. Furthermore, the trade-off between waiting time, walking time, and other factors of pedestrians are estimated using RRM in a panel mixed multinomial logit model. Moreover, the effects of unobserved heterogeneity and panel data are accounted for (Mannering et al., 2016). The findings shed light on the design and planning of crossing facilities to promote walkability and improve pedestrian safety.

2. METHOD

2.1 Stated preference experiment


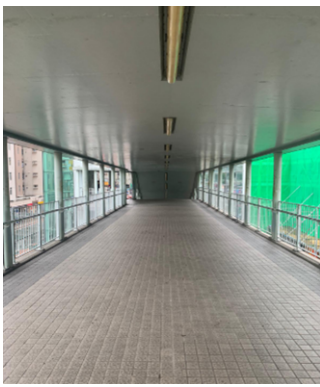

To gauge the trade-off between waiting time at traffic signals and additional walking time of pedestrians to use footbridges and underpasses, a stated preference (SP) experiment is adopted. The SP choice sets are presented based on a hypothetical scenario of walking travel. The pedestrian is assumed to be facing three crossing alternatives (i.e., signalized crossing, footbridge and underpass) and makes crossing decisions based on the given information. Important attributes and

relevant levels are guaranteed to reflect their influence on pedestrian preferences. **Table 1** presents the attributes and levels considered in the experiment. A pilot study was conducted to identify the key attributes prior to the choice experiment. 25 people were recruited through the publicity in university campus. Information on demographics and socioeconomics should be provided. Additionally, eight SP scenarios were given in each questionnaire. However, not all potential attributes could be included considering the complexity of choice set generation and efficiency of parameter estimation model. Eventually, five attributes including waiting time, extra walking time, weather condition, traffic condition, and crowdedness were included in the pilot survey. Results of pilot study justify the significance of the selected attributes. In the actual choice experiment, three alternatives (signalized crossing, footbridge, and underpass) are presented in each choice scenario. Additionally, four levels of waiting time at signalized crossings (0.5, 1, 1.5, and 2.5 minutes) and four combinations of additional walking time to access a footbridge or underpass are considered. The attribute levels of waiting time and walking time considered are consistent with those of the real-life experience of pedestrians in Hong Kong. In addition, as indicated in the “Introduction” section, rainy and extremely hot weather is prevalent in Hong Kong and could affect the preference for crossing facilities. Different weather conditions (i.e., 28°C and not raining, 28°C and raining, and 35°C and not raining) are considered, while 28°C and not raining is regarded as the base condition. In addition, traffic conditions (low, medium, and high) can affect the risk perception of pedestrians in choosing signalized crossings, which in turn affects the choice decision regarding the three crossing facilities. Furthermore, the effect of the crowdedness of crossing facilities on pedestrian choice is also investigated. In this study, no other pedestrians, several pedestrians and many pedestrians are considered. To improve the understanding of participants, the crowdedness of the crossing facilities is visualized in the questionnaire script based on actual scenes in the urban area of Hong Kong (see **Table 2** and **Appendix**). Notably, respondents are told that all grade-separated crossing facilities are equipped with elevators; therefore, they do not need to worry about vertical issues.

1 **Table 1. Attributes and levels considered in the stated choice experiment**

Attributes considered	Levels			
		Signalized crossing	Footbridge	Underpass
Waiting time at signalized crossing	Level 1	0.5 minute	0	0
	Level 2	1.0 minute	0	0
	Level 3	1.5 minutes	0	0
	Level 4	2.5 minutes	0	0
Extra walking time accessing to footbridge and underpass	Level 1	0	3 minutes	5 minutes
	Level 2	0	5 minutes	3 minutes
	Level 3	0	5 minutes	8 minutes
	Level 4	0	8 minutes	5 minutes
Weather condition	Level 1	28 °C and not raining		
	Level 2	28 °C and raining		
	Level 3	35 °C and not raining		
Traffic condition	Level 1	Low		
	Level 2	Medium		
	Level 3	High		
Crowdedness	Level 1	No other pedestrians		
	Level 2	Several pedestrians		
	Level 3	Many pedestrians		

2
3
4 **Table 2. Illustrations of crowdedness for different crossing facilities**

	Signalized crossing	Footbridge	Underpass
No other pedestrians (waiting at the kerbside for signalized crossing)			

Several pedestrians			
Many pedestrians			

Since there are five factors (each with three to four attribute levels), a full factorial design would have $(4 \times 4 \times 3 \times 3 \times 3 =)$ 432 combinations; however, this design is not efficient and practical for the measurement of pedestrian perception. Hence, an orthogonal fractional factorial design is adopted using the software package Minitab, reducing the number of choice scenarios to 16 (Bhat and Sardesai, 2006; Hössinger and Berger, 2012; Chen et al., 2020). Furthermore, the choice scenarios were blocked into four sets of four choice tasks using a randomized block design approach. Therefore, the online survey platform randomly allocated one of the four blocks of four SP scenarios to our respondents.

2.2 Perception questions and personal information

In addition to the stated choice experiment, the questionnaire also consisted of (a) preference for crossing facilities; (b) travel habits (i.e., commonly used transport mode, walking frequency per week); and (c) background information (socio-demographics). For the preference for crossing facilities, the perceived importance of issues including the presence of accessible facilities (i.e.,

ramped walkways, elevators, and moving staircases), extreme weather, traffic volume, crowdedness, natural ventilation, lighting, and security of pedestrians were gauged (see the **Appendix**). An online questionnaire survey was conducted during the period between 15 October 2021 and 30 November 2021 using the Credamo (www.credamo.com) platform. Inclusion criteria are inhabitants of Hong Kong aged 18 years or older. In the Credamo platform, information on personal characteristics including sex and age of the participants, who have to register using mobile phone number, is available. When there is a new questionnaire in the platform, invitations (three times of targeted sample size) would be made through email and text messages. To boost the participation, a remuneration of US\$3 would be given for each completed questionnaire. However, as the older population is under-represented in the Credamo platform, age distribution of the sample is skewed compared to that of Hong Kong population.

2.3 Method of analysis

As the dependent variable of the proposed model is categorical, with more than two unordered outcomes, a multinomial logit regression approach is considered. In addition, a panel mixed approach is adopted to account for the effect of unobserved heterogeneity and panel data (correlation between choice scenarios of the same individual) (Train, 2001, 2009; Chen et al., 2020). Moreover, both conventional RUM and proposed RRM models are estimated.

In the RUM model, the utility of alternative k ($k = 1, 2$, and 3) in choice scenario j ($j = 1, 2, 3$ and 4) of individual i ($i = 1, 2, \dots, I$) is given by (Hensher and Greene, 2003)

$$U_{ijk} = (\alpha' + \gamma_i')z_{ijk} + \xi_{ijk} \quad (\text{Eq. 1})$$

where z_{ijk} is a vector of variables, α' is a vector of coefficients that represent the mean effects, γ_i' denotes the normally distributed random effect ($\gamma_i' \sim N(0, \tau^2)$), and ξ_{ijk} is an identically and independently Gumbel distributed error term.

Then, the probability of k being chosen given γ_i' can be expressed as

$$P_{ijk} | \gamma_i' = \frac{e^{[(\alpha' + \gamma_i') z_{ijk}]}}{\sum_{k=1}^K e^{[(\alpha' + \gamma_i') z_{ijk}]}} \quad (\text{Eq. 2})$$

The unconditional probability is thus

$$P_{RUM} = \int_{\gamma_i'} (P_{ijk} | \gamma_i') dF(\gamma_i' | \tau) \quad (\text{Eq. 3})$$

where F is the multivariate cumulative normal distribution.

In the RRM model, the random regret RR_{ijk} of alternative k in choice scenario j of individual i is given by (Chorus, 2010; Iraganaboina, 2021)

$$RR_{ijk} = \sum_{s \neq k} \sum_{\forall m} \ln \{1 + \exp[(\beta' + \rho_i')(z_{ismj} - z_{ikmj})]\} \varepsilon_{ijk} \quad (\text{Eq. 4})$$

where z_{ikmj} is a vector of variables of chosen alternative k , z_{ismj} is that of unselected alternative s , α' is a vector of coefficients that represent the mean effects, ρ_i' denotes the normally distributed random effect ($\rho_i' \sim N(0, \sigma^2)$), and ε_{ijk} is an identically and independently Gumbel distributed error term.

Following regret theory, we assert that when making travel choices, people tend to anticipate and avoid the possibility that a nonchosen alternative has higher reward than the chosen alternative. This avoidance of anticipated regret, rather than the maximization of utility, is assumed to be specifically relevant in traveller behaviour (Chorus et al., 2008; Leong and Hensher, 2015). Then, the probability of k being chosen can be expressed as (McFadden, 1978)

$$P_{ijk} = \frac{e^{-RR_{ijk}}}{\sum_{k=1}^K e^{-RR_{ijk}}} \quad (\text{Eq. 5})$$

The unconditional probability is then

$$P_{ik} = \int_{\rho_i'} (P_{ijk} | \rho_i') dF(\rho_i' | \sigma) \quad (\text{Eq. 6})$$

where F is the multivariate cumulative normal distribution.

For the observed choice sequence of individual i , the likelihood function conditional on ρ_i is written as

$$L_i(\alpha | \rho_i) = \prod_{j=1}^J [\prod_{k=1}^K \{P_{ijk} | \rho_i\}^{\delta_{ijk}}] \quad (\text{Eq. 7})$$

where δ_{ijk} is an indicator variable that takes a value of 1 when alternative k is chosen and 0 otherwise.

Finally, the unconditional likelihood function is given by

$$L_i(\alpha, \sigma) = \int_{\rho_i} L_i(\alpha | \rho_i) dF(\rho_i | \sigma) \quad (\text{Eq. 8})$$

Parameter estimation of the proposed random parameter model is performed using NLOGIT (Version 6.0) software (Greene, 2016). If the standard error of a parameter is statistically significant at the 10% level, then the parameter is specified as “random”. The model is estimated using the simulated maximum likelihood with 200 Halton draws (Train, 2009). In addition, a stepwise iterative approach is applied to assess the random parameter (Arentze and Timmermans, 2007; Islam and Jones, 2014; Zhai et al., 2019). The variables are tested one by one, and the iterative process continues until the improvement in overall model fit is negligible.

A simulation approach is applied to estimate the parameters that maximize the likelihood function. Under weak regularity conditions, the maximum simulated likelihood (MSL) estimator is consistent, asymptotically efficient, and asymptotically normal (see Hajivassiliou and Ruud, 1994; McFadden and Train, 2000). Furthermore, the Halton sequence is applied to draw realizations for ρ_i from the prevailing normal distributions. For the details of the Halton sequence, readers may refer to Bhat (2001, 2003) and McFadden and Train (2000). With the Halton sequence, draws from a single observation can fill all the empty spaces. Therefore, the simulated probabilities are negatively correlated, which reduces the variance of the log-likelihood function. Notably, a

negative correlation remains in the simulated probabilities between observations, even when some attributes in different observations (of the same panel) are identical (Train, 2001).

3. Data and sample description

A total of 500 participants completed the questionnaire survey. **Table 3** summarizes the characteristics of the participants. Overall, ratio of male to female is 689 to 1,000. It is consistent to that of Hong Kong population (ratio of male to female equal to 838 to 1,000) (Census and Statistic Department, 2021a). For the age, participants of age between 18 and 25 years constitute more than one-third (37.8%). It is much higher than that of Hong Kong population (7.9%). On the other hand, participants of age more than 56 years constitute 12.2%. It is extremely lower than that of Hong Kong population (38.2%) (Census and Statistic Department, 2021a). For the education level, majority of participants has attended tertiary education or above (81.2%). It is higher than that of Hong Kong population (35.6%) (Census and Statistic Department, 2021b). For the occupation, 61.0% of participants are working full-time, 30.0% are students, and 9.0% are not working full-time respectively. Again, it does not align with Hong Kong population (Census and Statistic Department, 2021c). Misalignment can also be observed for monthly income. In the sample, approximately one-third (31.4%) earned less than HKD 10,000 per month, and approximately half (49.0%) earned between HKD 10,000 and HKD 20,000 per month. In terms of travel habits, over two-thirds (68.4%) of participants walked more than six times per week, and over half (51.8%) walked for more than 2 hours per week. For the transport mode, metro (82.8%) and bus (50.4%) were commonly used by the participants.

Table 3. Distribution of the sample

Category	Variable	Attribute	Count	Percentage	Proportion in Hong Kong Population
Demographics	Sex	Male	204	40.8%	45.6%
		Female	296	59.2%	54.4%

	Age	18–25 years	189	37.8%	7.9%
		26–35 years	100	25.0%	15.7%
		36–45 years	84	16.8%	18.2%
		46–55 years	66	13.2%	18%
		56 years or above	61	12.2%	38.2%
Socioeconomics	Education level	Secondary or below	95	19.0%	64.4%
		Tertiary or above	405	81.0%	35.6%
	Occupation	Full-time	305	61.0%	49.6%
		Not working full-time/retired	45	9.0%	30.6%
		Student	150	30.0%	19.8%
	Monthly income	Less than HKD 10,000	157	31.4%	10.2%
		HKD 10,000-19,999	245	49.0%	38.8%
		HKD 20,000-29,999	77	15.4%	26.8%
		HKD 30,000 or more	21	4.2%	24.2%
Travel habit	Walking frequency per week	Less than 2 times	6	1.2%	Not available
		2–5 times	152	30.4%	
		6–10 times	206	41.2%	
		More than 10 times	136	27.2%	
	Walking time per week	Less than 0.5 hour	7	1.4%	
		0.5–2 hours	234	46.8%	
		2–6 hours	180	36.0%	
		More than 6 hours	79	15.8%	
	Commonly used transport mode ^{Note}	Private car	186	37.2%	
		Bus	252	50.4%	
		Taxi	164	32.8%	
		Metro	414	82.8%	
		Bicycle	148	29.6%	
		Tram	71	14.2%	

Note: More than one transport mode could be selected

4. ANALYSIS RESULTS

4.1 Descriptive analysis

Since there are four choice scenarios in each questionnaire, the total number of observations is 2,000. Among the 2,000 scenarios, signalized crossing, footbridge, and underpass are preferred in

641 (32.0%), 784 (39.2%), and 575 (28.8%) scenarios, respectively. Figure 1 shows the distribution of choice frequency. As shown in Figure 1, the frequency of choosing signalized crossing increases as the waiting time decreases (Figure 1(a)), traffic volume decreases (Figure 1(c)), and when the weather is 28 °C and not raining (Figure 1(d)).

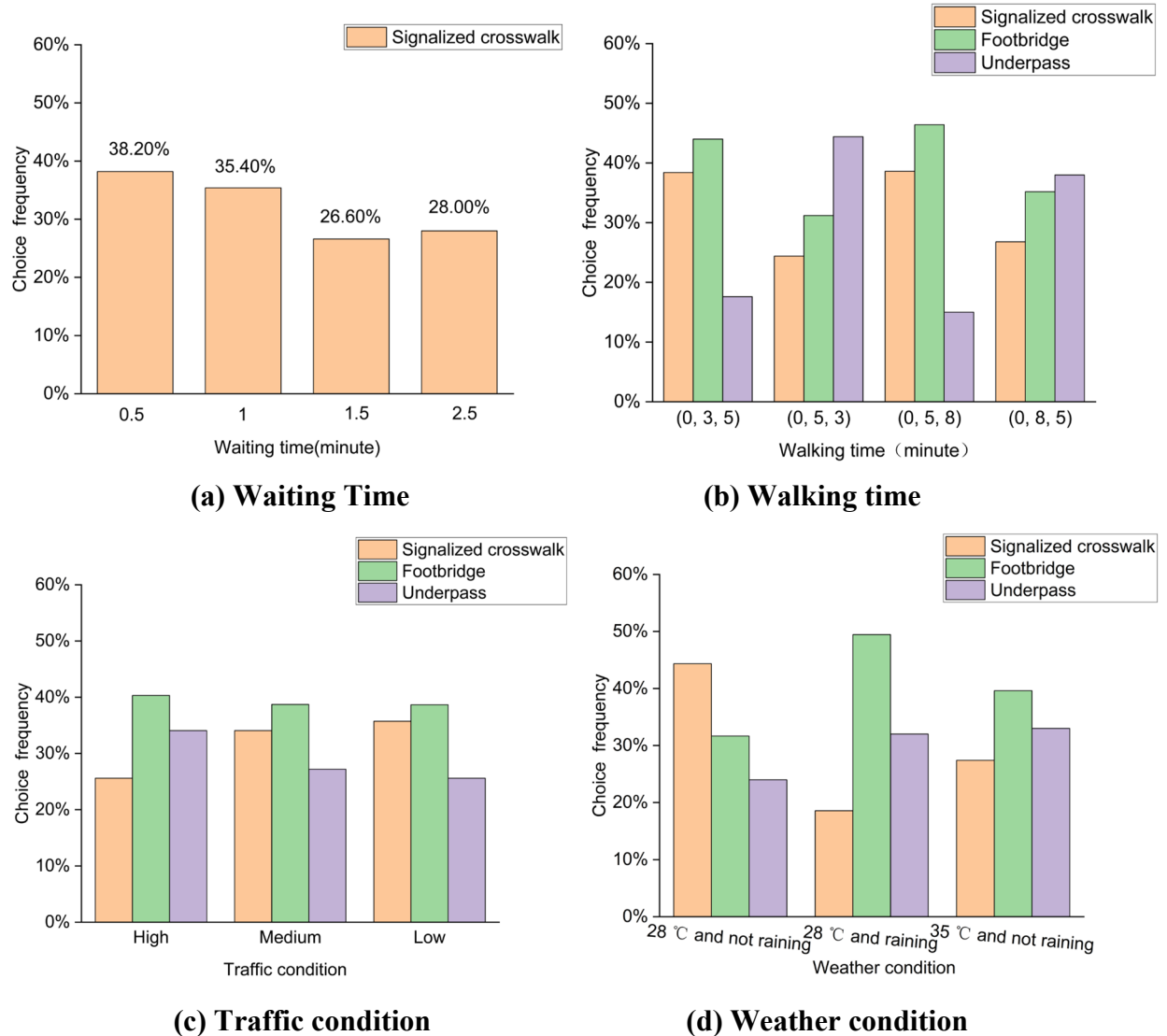


Figure 1. Distribution of choice probability for crossing facilities

Table 4 summarizes pedestrians' perceptions of different design and environmental factors of crossing facilities. For the footbridge, pedestrians considered route familiarity, presence of accessible design (e.g., elevator and moving staircase), and weather as important influencing

factors in the choice decision. Specifically, footbridges with moving staircases are the most preferred, and those with elevators are preferred over those with ramped walkways. In addition, footbridges with moderate pedestrian flow are preferred to those with no pedestrians. On the other hand, for the signalized crossing, pedestrians considered traffic volume, size of pedestrian island, and length of crossing (e.g., road width) as important. For example, crossings with low traffic volume and large pedestrian islands are preferred. Furthermore, for the underpass, pedestrians considered lighting, natural ventilation and the presence of other pedestrians to be important. Again, underpasses with moving staircases are preferred to those with elevators and ramped walkways. Additionally, underpasses with moderate pedestrian flow are preferred to those with no pedestrians.

Table 4. Importance and preference of design and environmental factors

		Mean	St.d
Footbridge			
<i>Importance (1-Not important, 7-Very important)</i>			
With a lift or elevator		5.39	1.43
Route familiarity		5.53	1.17
Weather condition		5.34	1.42
<i>Preference (sort score, 1- most preferred)</i>			
Elevator	No elevator and no ramp	3.26	1.05
	Ramped walkways	2.93	0.82
	Lift elevator	2.11	0.89
	Moving staircases	1.69	0.90
Pedestrian volume	No other pedestrians	1.92	0.81
	Several pedestrians	1.55	0.57
	Many pedestrians	2.52	0.74
Signalized crosswalks			
<i>Importance (1-Not important, 7-Very important)</i>			
Length of the crosswalks		5.52	1.25
Traffic condition		5.93	1.07
Size of the central island		5.69	1.15
<i>Preference (sort score, 1- most preferred)</i>			

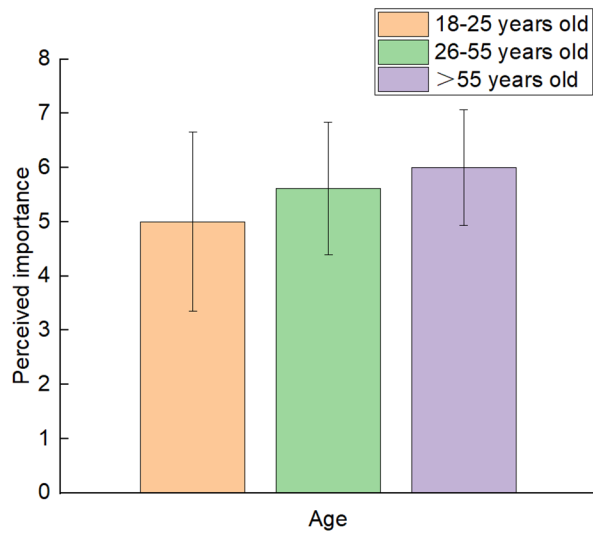
Central island	No central island	2.68	0.67
	A central island one-metre wide	1.88	2.55
	A central island two-metres wide	1.44	0.68
Traffic volume	No vehicle	1.38	0.73
	A few vehicles	1.92	0.42
	Many vehicles	2.70	0.65
Pedestrian volume	No other pedestrians	1.68	0.79
	Several pedestrians	1.67	0.53
	Many pedestrians	2.64	0.68
Underpass			
<i>Importance (1-Not important, 7-Very important)</i>			
Natural ventilation		5.84	0.98
Artificial lighting		6.23	0.82
Presence of other pedestrians		5.28	1.22
<i>Preference (sort score, 1- most preferred)</i>			
Elevator	No elevator and no ramp	3.42	0.99
	Ramped walkways	2.77	0.78
	Lift elevator	2.08	0.85
	Moving staircases	1.73	1.01
Presence and number of other pedestrians	No other pedestrians	1.87	0.82
	Several pedestrians	1.55	0.54
	Many pedestrians	2.57	0.69

4.2 Perceived importance and preference

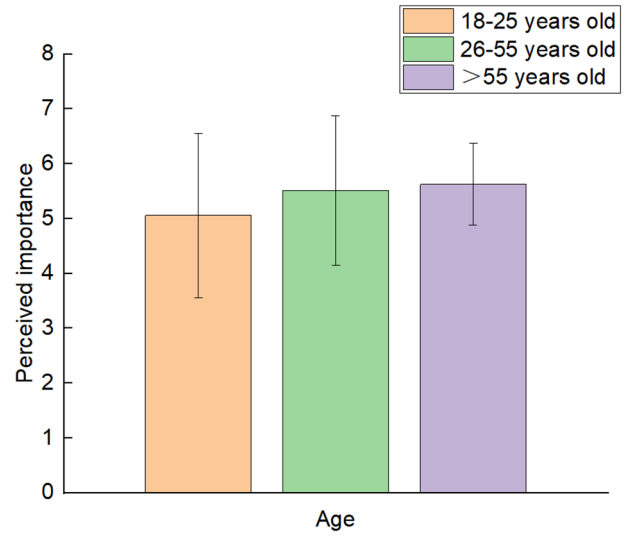
The Kruskal–Wallis test was adopted to examine the difference in the perceived importance of design and environmental factors among pedestrian groups (Anhê et al., 2020). For example, gender and age significantly affect the perceived importance of (i) the presence of elevators, (ii) weather, (iii) temperature, (iv) natural ventilation, and (v) crowdedness for the likelihood of using footbridges and underpasses at the 5% level of significance. As shown in **Figure 5**, for the likelihood of using footbridges, younger pedestrians aged between 18 and 25 years considered the presence of elevators, weather, and temperature to be less important than did other pedestrian groups, possibly because younger pedestrians are less sensitive to accessible design and outdoor

environment for the choice decision (Ojo et al., 2022). In addition, female pedestrians considered the presence of elevators to be more important than did male pedestrians, which is consistent with the findings of previous studies. Female pedestrians prefer elevators to staircases because of their physical capability (Forsyth et al., 2009; Karekla and Tyler, 2018). This is indicative of the planning of accessible designs for footbridges. For the likelihood of using an underpass, younger (age 18-25) and older (age over 55) pedestrians considered natural ventilation to be less important (Cheng et al., 2021). Furthermore, younger pedestrians are less sensitive to the presence of other pedestrians in the underpass. This is indicative of the design and planning of underground walkway systems for areas with more schools and youth centres.

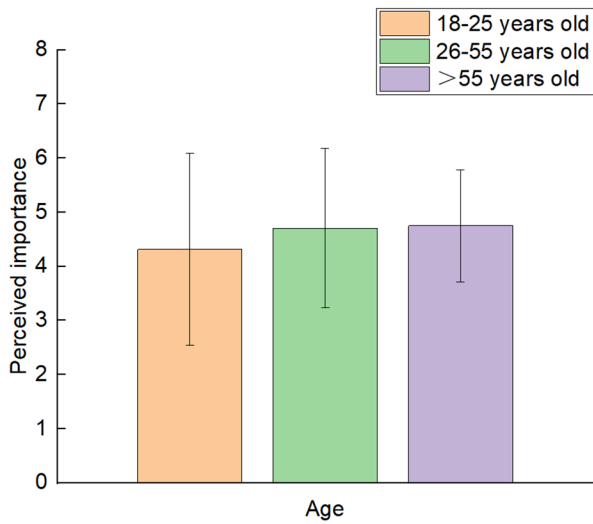
Figure 6 illustrates the differences in the preferences regarding crossing facilities among different pedestrian groups. As shown in **Figure 6(a)** and **Figure 6(b)**, footbridges with moving staircases are the most preferred. In addition, footbridges with elevators are preferred over those with ramped walkways, regardless of the pedestrian group. This is not surprising, as moving staircases substantially improve accessibility (Olander and Eves, 2011). It is necessary to consider the life cycle cost (i.e., capital, installation, repair, and maintenance cost) and level of service (pedestrian demand versus capacity) for the implementation of moving staircases and other accessible designs (Ding et al., 2015; Zhu, 2020; Wałach and Kaczmarczyk, 2021; Vivek et al., 2022). In terms of traffic conditions, as shown in **Figure 6(c)**, when there is high traffic flow, signalized crossings are the least preferred, regardless of pedestrian age.



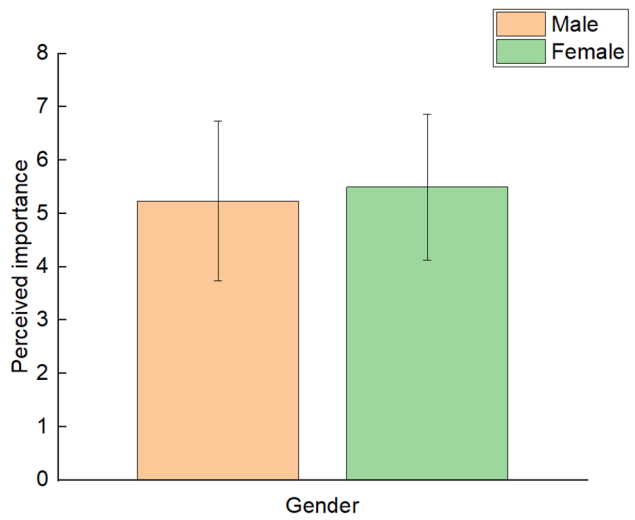
(a) Footbridge - Elevator (Age)



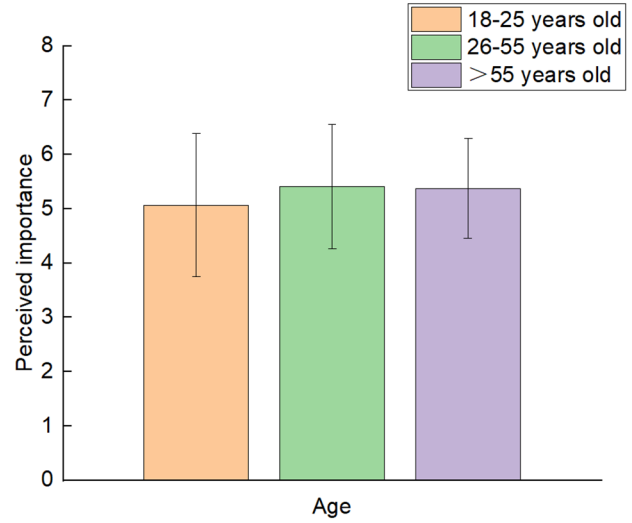
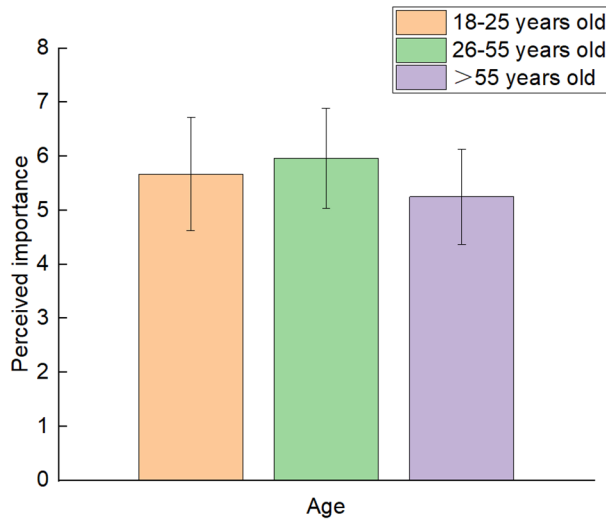
(b) Footbridge - Weather (Age)



(c) Footbridge - Temperature (Age)



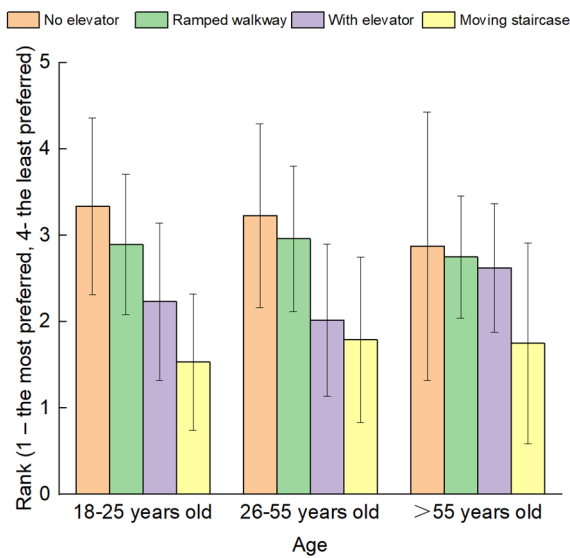
(d) Footbridge - Elevator (Gender)



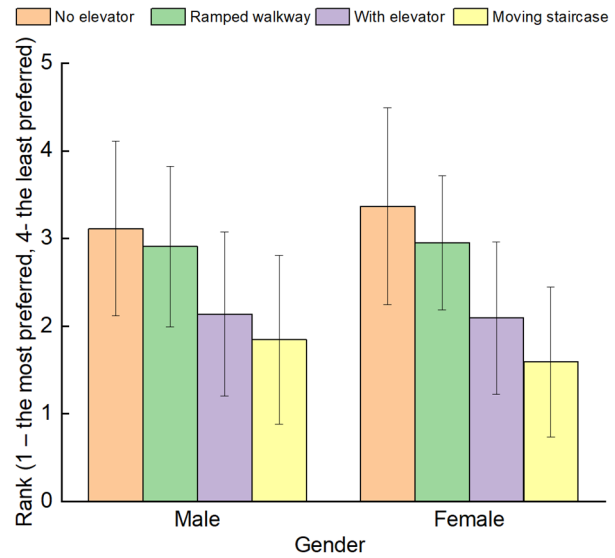
(e) Underpass - Natural ventilation (Age)

(f) Underpass – Crowdedness (Age)

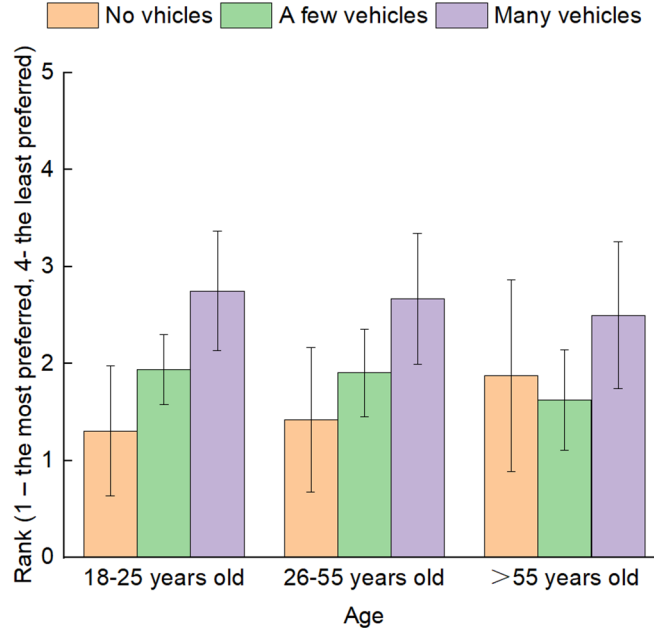
Figure 5. Perceived importance of different design and environmental factors



(a) Footbridge – Elevator (Age)



(b) Footbridge – Elevator (Gender)



(c) Signalized crossing – Traffic flow (Age)

Figure 6. Preferences of footbridge and signalized crossing for different pedestrian groups

4.3 Model results

Table 5 presents the results of panel mixed multinomial logit models for pedestrians' choice of crossing facilities. As shown in **Table 5**, the RRM model outperformed the RUM model, with a lower Akaike information criterion (AIC). In the following, we focus on the parameter estimation results of the RRM model.

For the waiting time (at signalized crossing) and walking time (access to footbridge or underpass), as expected, pedestrians' tendency to use a footbridge or underpass increases as the waiting time at a signalized crossing ($\beta = 0.412$) increases at the 1% level of significance. In contrast, the tendency to use footbridges and underpasses decreases significantly when the extra walking time increases (-0.183), again at the 1% level. For the weather condition, pedestrians tend to use footbridges and underpasses when it is 28°C and raining (footbridges: 1.520; underpasses: 1.075) and 35°C and not raining (footbridges: 0.935; underpasses: 1.220), both at the 1% level of significance. In terms of traffic conditions, pedestrians tend to use footbridges and underpasses

when traffic volume is high (footbridges: 0.727; underpasses: 0.684) at the 5% level of significance. Furthermore, pedestrians' tendency to use footbridges is significantly lower when there are no other pedestrians (-0.227) and when it is too crowded (-0.419) compared to that with moderate pedestrian traffic, at the 5% level. However, crowdedness has no significant effect on pedestrians' tendency to use underpasses.

For personal characteristics, the tendency of females to use footbridges and underpasses is significantly lower (footbridges: -0.134; underpasses: -0.147) than that of males at the 5% level. On the other hand, young pedestrians have a higher tendency to use footbridges and underpasses (footbridges: 0.342; underpasses: 0.467) at the 5% level of significance. In contrast, pedestrians with tertiary education or above have a lower tendency to use footbridges and underpasses (footbridges: -0.541; underpasses: -0.394) at the 5% level of significance. Furthermore, pedestrians' tendency to use underpasses is higher when their monthly income is HKD 20,000 or above (0.445) at the 5% level of significance. Finally, the tendency to use footbridges is higher for full-time workers (0.517) at the 5% level of significance.

Regarding travel habits, pedestrians who walk less (less than 2 hours) have a higher tendency to use footbridges and underpasses (footbridges: 0.143; underpasses: 0.275) at the 5% level of significance. On the other hand, pedestrians who use the metro have a higher tendency to use footbridges and underpasses (footbridge: 0.189; underpass: 0.302) at the 5% level of significance.

Interaction effects between personal characteristics and environmental factors on the choice of crossing facilities are also considered. As shown in **Table 5**, there are significant interactions between gender, rain conditions, and traffic conditions for pedestrians' choices. Under rainy conditions, female pedestrians have a higher tendency to use footbridges and underpasses (footbridges: 0.408; underpasses: 0.467) at the 5% level of significance. Additionally, pedestrians have a higher tendency to switch to footbridges when traffic volume is high (1.384). On the other

1 hand, there is a significant interaction between age group and walking time. For young pedestrians
2 aged between 18 and 25 years, the tendency to use underpasses decreases as the additional walking
3 time increases (-0.035) at the 5% level of significance. Finally, for pedestrians who have higher
4 incomes (more than HKD 20,000 per month), the tendency to use underpasses decreases (-0.958)
5 when it is 35°C and not raining at the 1% level of significance.

Table 5. Results of parameter estimation of the panel mixed multinomial logit model

Scope of work	Factor	Attribute	RRM model (Omitted choice: signalized crossing)					RUM Model (Omitted choice: signalized crossing)			
			Footbridge			Underpass		Footbridge		Underpass	
			Coefficient		S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
	Constant		0.658^		0.325	IS		0.983^	0.510	IS	
Stated choice attributes	Waiting time at signalized crossing		Mean	0.412**	0.076	0.412**	0.076	0.641**	0.124	0.641**	0.124
			SD	0.401**	0.053	0.401**	0.053	0.583**	0.098	0.583**	0.098
	Extra walking time accessing to footbridge or underpass		-0.183**		0.025	-0.183**	0.025	-0.272**	0.041	-0.272**	0.041
	Weather condition (Omitted category: 28 °C and not raining)	28 °C and raining	1.520**		0.193	1.075**	0.230	1.112**	0.312	1.389**	0.314
		35 °C and not raining	0.935**		0.167	1.220**	0.194	1.128**	0.231	1.641**	0.271
	Traffic volume (Omitted category: Medium)	Low	IS			-0.236*	0.091	-0.727*	0.301	-0.548*	0.257
		High	0.727*		0.135	0.684**	0.192	0.802**	0.213	1.062**	0.205
	Crowdedness (Omitted category: Several pedestrians)	No other pedestrians	-0.227*		0.101	IS		-0.324^	0.187	IS	
		Many pedestrians	-0.419*		0.221	IS		-0.368*	0.121	IS	
	Socio-demographics	Sex	Female	Mean	-0.134*	0.061	-0.147*	0.072	-0.212*	0.067	-0.247*
SD				0.156**	0.054	0.153**	0.065	0.235**	0.101	0.265**	0.092
Age		18-25 years old	0.342^		0.162	0.476*	0.274	0.518^	0.280	0.778*	0.377

	Educational level	Tertiary or above	-0.541*	0.218	-0.394*	0.201	-0.891*	0.371	-0.670*	0.291
	Monthly income (Omitted category: 10000-20000 HKD)	Less than HKD 10,000	IS		IS		IS		IS	
		More than HKD 20,000	IS		0.445*	0.184	0.307^	0.165	0.659**	0.238
	Occupation	Working full-time	0.157*	0.104	0.147^	0.081	0.310^	0.168	1.672^	0.812
Travel habit	Walking time per week (Omitted category: 2–6 hours)	Less than 2 hours	0.143*	0.081	0.275*	0.126	0.220^	0.145	0.414*	0.166
		More than 6 hours	IS		IS		IS		IS	
	Commonly used transport mode	Bus	IS		-0.256^	0.142	IS		-0.031^	0.016
		Taxi	0.089^	0.046	IS		-0.083^	0.051	IS	
		Metro	0.189*	0.091	0.302*	0.138	0.280*	0.121	0.437*	0.207
Interaction effect	Female x Raining		0.408*	0.195	0.467*	0.215	0.601*	0.276	0.687*	0.299
	18-25 years old x Extra walking time accessing to footbridge or underpass		IS		-0.035*	0.021	IS		-0.107*	0.420
	More than HKD 20,000 x 35°C and not raining		IS		-0.958**	0.256	IS		-1.533**	0.481
	High traffic volume x 28°C and raining		1.384*	0.473	IS		1.247**	0.312	IS	
Restricted log likelihood			-2184.7				-2191.7			
Unrestricted log likelihood			-1963.3				-1966.3			
McFadden Pseudo R-square			0.22				0.21			
AIC			4021.9				4026.5			

1 Notes: ** Statistically significant at the 1% level; * Statistically significant at the 5% level; ^ Statistically significant at the 10% level; IS denotes nonsignificant

4.4 Trade-off between waiting and walking time

As expected, the tendency to use footbridges or underpasses increases when the waiting time at traffic signals increases and the extra walking time decreases. In addition, the effect of the waiting time at a traffic signal is normally distributed with a mean of 0.412 and a standard deviation of 0.401. This implies that there is an 84.9% probability that pedestrians would switch to footbridges or underpasses when the waiting time at traffic signals increases. Thus, it is worth investigating the trade-off between waiting time and walking time by estimating the ratio of perceived value of waiting time to that of walking time using the formulation given by (Chorus, 2010; Iraganaboina, 2021),

$$R_{value} = \frac{\sum_{s \neq k} -\beta_t (1 + \frac{1}{e^{\beta_t (t_k - t_s)}})}{\sum_{s \neq k} -\beta_r (1 + \frac{1}{e^{\beta_r (r_k - r_s)}})} \quad (\text{Eq. 9})$$

where β_t is the parameter of waiting time, β_r is the parameter of extra walking time, t_k and t_s are the waiting times for alternatives k and s , and r_k and r_s are the walking times for alternatives k and s , respectively.

Figure 2 illustrates the variation in the ratio of perceived value across waiting time and extra walking time. As shown in **Figure 2**, the ratio ranges from 0.15 to 0.51 given that the waiting time at the traffic signal is less than 2.5 minutes and the extra walking time to access a footbridge or underpass is less than 15 minutes. In other words, pedestrians are less tolerant of waiting at traffic signals, and they perceive that waiting for 0.15 to 0.51 minutes is equivalent to walking for 1 minute.

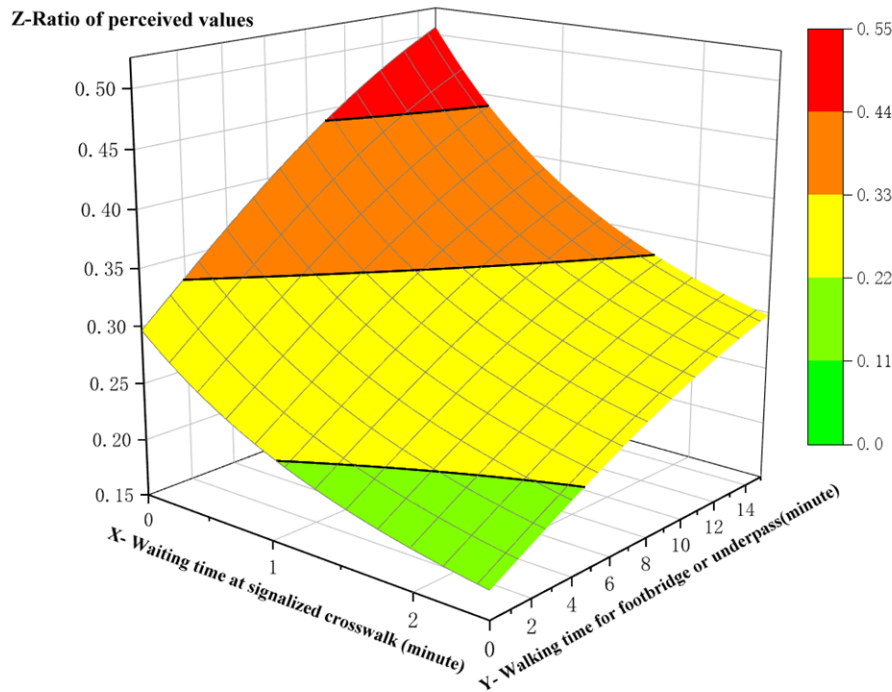
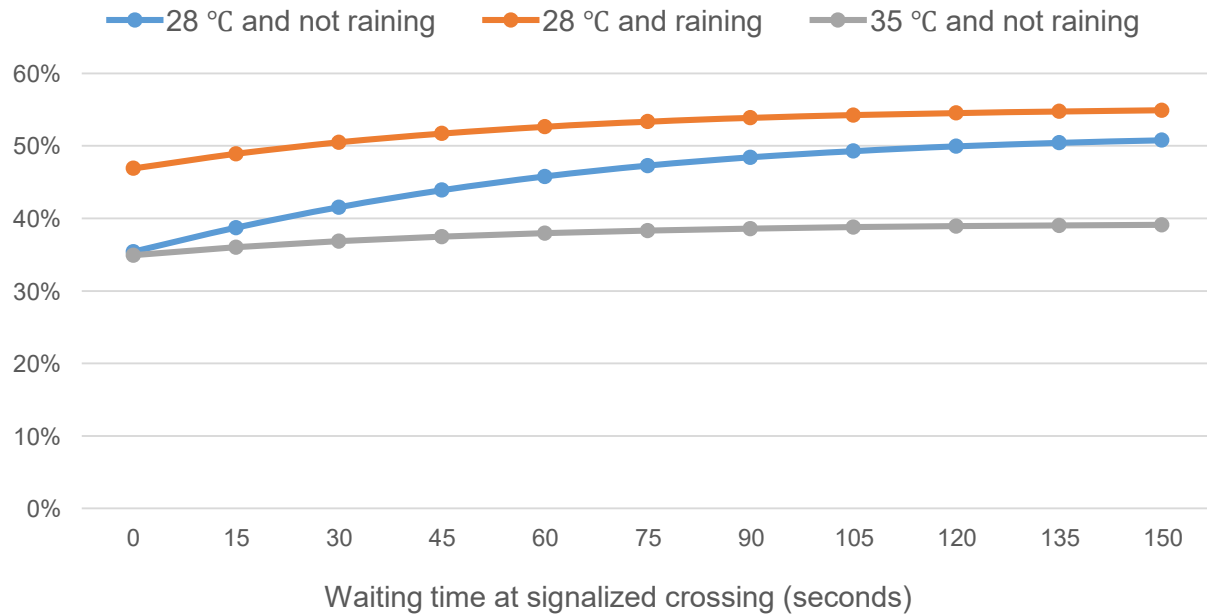


Figure 2. Ratio of perceived values with respect to waiting time and walking time

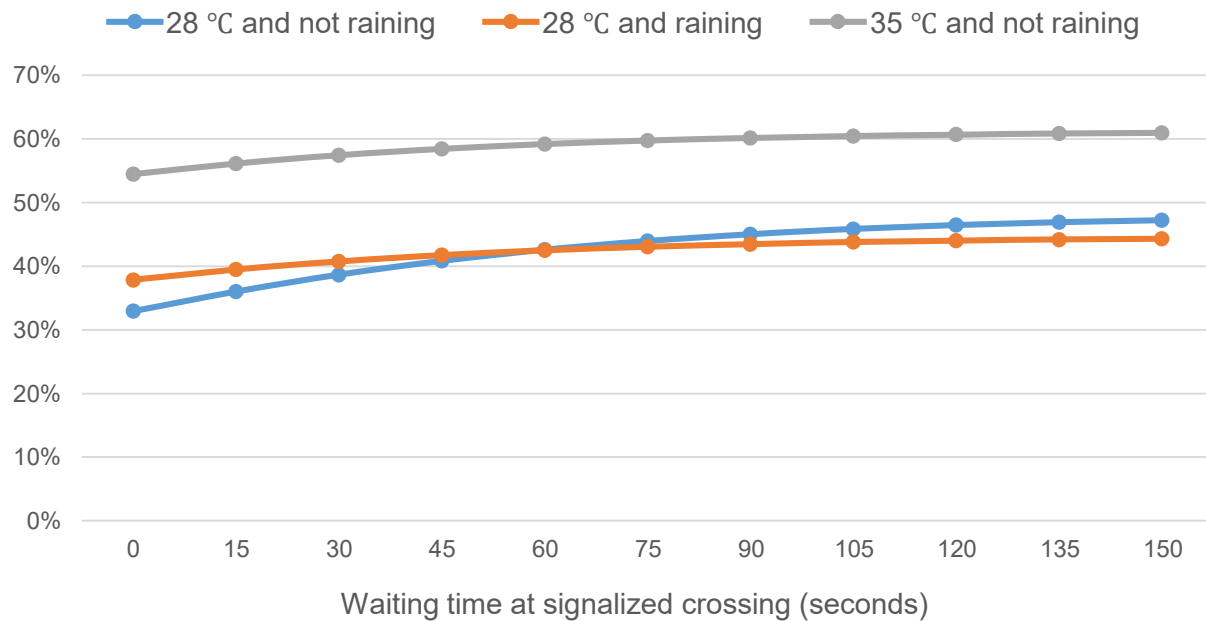
4.5 Environmental conditions

The likelihood of using footbridges and underpasses increases when it is raining and 35°C since waiting at traffic signals would be very unpleasant in adverse weather (Yang et al., 2015). The positive association between the likelihood of using footbridges and traffic volume is magnified when it rains because pedestrians tend to be more risk-averse under poor weather conditions. Adaptive behaviour is more prevalent to compensate for the risk attributed to high traffic flow (Agdas et al., 2017). For the effect of crowdedness, the likelihood of using footbridges and underpasses is lower when there are no other pedestrians and when it is overcrowded compared to that with moderate pedestrian volume. This finding is consistent with those of previous studies. This may be because of the safety and security concerns of pedestrians, who tend to avoid using underpasses that have no other pedestrians. However, the perceived comfort level of the walkway should be considered (Zhou et al., 2016; Anciaes and Jones, 2018; Cook et al., 2022).

Figure 3 shows the changes in the likelihood of using footbridges and underpasses with respect to the waiting time at signalized crossings in different weather conditions (i.e., 28 °C and not raining, 28 °C and raining, and 35 °C and not raining). As shown in **Figure 3(a)**, the likelihood of using footbridges in 28 °C and raining is higher than that in 28 °C and not raining and 35 °C and not raining. The likelihood of using footbridges in rainy conditions increases as the waiting time at signalized crossing increases. As discussed, this could be attributed to the unpleasant feeling of waiting at the kerbside in rain (Yang et al., 2015). In contrast, as shown in **Figure 3(b)**, the likelihood of using underpasses in 35 °C and not raining is higher than that in 28 °C and not raining and in 28 °C and raining. This could be because underpasses tend to be cooler in hot weather (Moretti and Loprencipe, 2018). Hence, the probability of using an underpass in extremely hot weather conditions increases as the waiting time at the signalized crossing increases.



(a) Footbridge



(b) Underpass

Figure 3. Likelihood of using footbridges and underpasses in different weather conditions

4.6 Personal characteristics

The likelihood of using footbridges and underpasses is higher for male and young (age between 18 and 25 years) pedestrians. The gender effect is normally distributed (standard deviation: footbridge, 0.156; underpass, 0.153). This implies that female pedestrians are 19.5% and 16.8% more likely to use footbridges and underpasses than are male pedestrians. On the other hand, pedestrians who have attained higher education have a lower likelihood of using footbridges and underpasses. Such findings are consistent with those of previous studies (Rosenbloom, 2009; Guo et al., 2011; Brosseau et al., 2013; Zhang et al., 2016; Zhu et al., 2021a). **Figure 4** illustrates the changes in the likelihood of using footbridges and underpasses with respect to waiting time and walking time for overall and young pedestrians. As shown in **Figure 4(b)** and **4(d)**, the likelihood of young pedestrians using footbridges and underpasses is sensitive to changes in waiting time and walking time. Moreover, pedestrians with higher incomes and full-time jobs are more likely to use footbridges and underpasses. This could be because of the high travel intensity for these pedestrian

groups. In particular, 90% of daily passenger trips in Hong Kong are made by public transportation, and footbridges and underpasses are well connected with the metro system in the city (Turner and Niemeier, 1997; Schwanen and Dijst, 2002; Hong Kong Building Department, 2011; Hong Kong Transport Department, 2014).

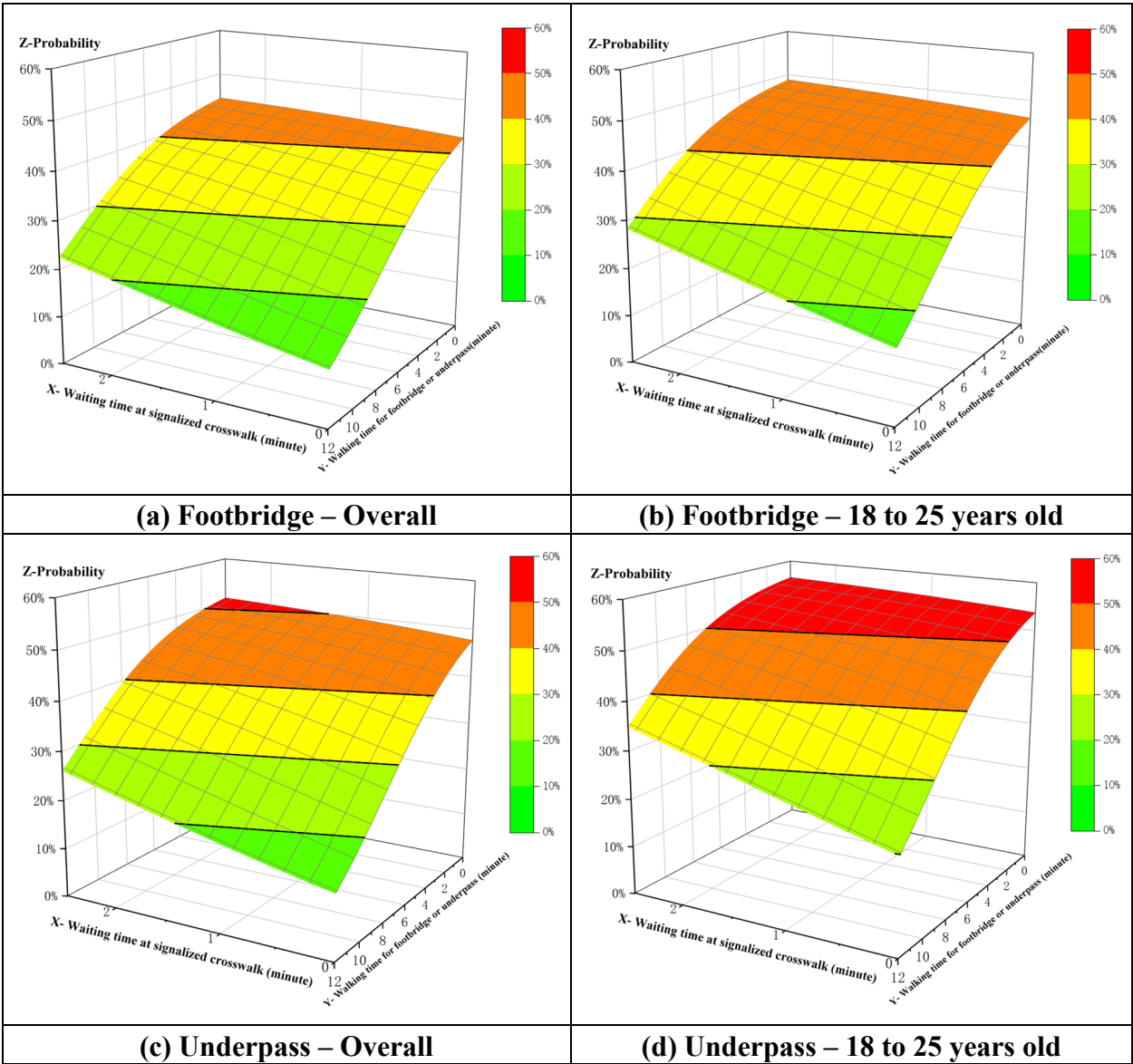


Figure 4. Intentions to use footbridges and underpasses between different age groups

5. DISCUSSION

5.1 Summary of influencing factors

Table 6 summarizes the factors that affect pedestrians' choice of crossing facility identified in this study. The findings are generally consistent with those of previous studies, particularly for waiting time, walking time, traffic conditions, crowdedness and pedestrian characteristics.

As the main findings in this research, the variables that represent weather conditions, income and interaction effects (Female x Raining) have a significant impact on the signalized crossing, footbridge, and underpass route decisions. The results suggest that a footbridge/underpass route is more likely to be chosen if *it is raining or 35°C*. The positive effect is coherent with the fact that travellers try to take more comfortable paths under such weather conditions, as suggested in a study of transport mode choices (Böcker et al., 2016). For the *income* variable, pedestrians with higher income prefer using footbridges and underpasses. This may be explained by the differences in cognitive representations of the same environment between individuals based on their incomes, as suggested by the empirical studies of Dewulf et al. (2012) and Roda et al. (2016). In our case, it could be associated with the perceptions of safety, comfort level and additional effort associated with the extra waiting and walking time.

Gender-related pedestrian studies are promising for interpreting the interaction effects - Female x Raining. For instance, Hidayati et al. (2020) suggested that women are more likely to report negative perceptions of safety than are men. Patra et al. (2020) reported that the crossing choices of women and older pedestrians are influenced primarily by convenience. We suggest that, at least in the case of Hong Kong, women may consider footbridge/underpass routes to be safer, while the perceived convenience of using signal crossings is reduced due to weather conditions.

Notably, our results on the effects of occupation are not consistent with two recent studies by Chandrappa et al. (2021) and Bhatia et al. (2022), who found that students were less likely to use

grade-separated facilities than were servicemen. The results may seem counterintuitive, but they point to the fact that “occupation/employment”, which is often included in studies of pedestrian route choice, potentially captures the effect of the differences in walking habits for people of different employment statuses. The association between occupation/employment and route choice is unclear, as revealed by the recent systematic review by Basu et al., 2022, but it may be potentially associated with other factors, for instance, the experienced ‘time pressure’ for different trip purposes (Eswar and Shankar, 2021), differences in perceptions about walking and pedestrian facilities (Tsukaguchi et al., 2013), and variation in the utility of walking by time, distance and degree of convenience among different employment statuses (Hatamzadeh et al., 2017). In addition, a cross-country study by Guo and Loo (2013) documenting subjective walkability, including ratings of the numbers and waiting time of street crossings, revealed the effects of differences in cultural background and resident lifestyle. Our results from a case in Hong Kong supplement other studies on the utilization of underground space by revealing that the effect of occupation/employment varies in different urban settings.

Table 6. Effects of influencing factors revealed in this study

Scope of work	Attribute	Current study	Previous studies	
Stated choice attributes	Waiting time	↑	↑	Yang et al., 2015
	Extra walking time to access a footbridge or underpass	↓	↓	Pedersen and Frier, 2010; Anciaes and Jones, 2020
	Raining	↑	Rarely attempted	
	Extremely hot weather	↑	Rarely attempted	
	Traffic volume	↑	↑	Agdas et al., 2017; Rankavat and Tiwari, 2020
	Crowdedness	Nonlinear	No-linear	Anciaes and Jones, 2018
Socio-demographics	Female	↓	↓	Rosenbloom, 2009; Guo et al., 2011
	Young adult	↑	↑	Brosseau et al., 2013; Zhang

				et al., 2016
	Educational level	↓	↓	Harada et al., 2008; Zhu et al., 2021
	Monthly income	↑		Rarely attempted
	Occupation	↑	↑	Chandrappa et al., 2021; Bhatia et al., 2022
Travel habit	Walking time per week	↑		Zhu et al., 2021a
	Use of metro	↑	↑	Rankavat and Tiwari, 2020
Interaction effect	Female x Raining	↑		Rarely attempted

Notes:

↑ refers to a higher tendency to use footbridges and underpasses

↓ refers to a lower tendency to use footbridges and underpasses

5.2 Policy implications

Hong Kong's densely packed development and high traffic volumes places significant constraints on its walking safety improvement. This study examines the roles of waiting time and walking time in the choice of pedestrians to use footbridges and underpasses, with which the influences of personal characteristics and weather conditions are considered. In this section, we discuss the implications for a) walkability and safety improvement, b) transport infrastructure design practices and c) pedestrian accessibility and equity.

5.2.1 Walkability and safety improvement

Improving walkability and safety is one of the major goals of building grade-separated pedestrian systems (Cui et al., 2010; 2019). Considering subjective *walkability*, our results indicate that pedestrians are more sensitive to an increase in waiting time at traffic signals than an increase in walking time to access footbridges and underpasses. This sensitivity increases in adverse weather conditions such as rain and extremely high temperatures. This may be because accessible design is commonly adopted for pedestrian facilities in Hong Kong. For example, a large number of elevators and movable staircases have been installed at footbridges and underpasses in the past

decade (Hong Kong Building Department, 2011). It is worth exploring the influence of vertical access (i.e., staircases, ramped walkways, and elevators) on the choice of pedestrians in future research (Venuti et al., 2016). On the other hand, the results are informative of the optimal traffic signal time plan at signalized crossings that can maximize pedestrian safety and minimize traffic delay. For example, pedestrian green time can be adaptive to pedestrian volume; therefore, traffic delays can be reduced when pedestrian volume is low. Additionally, the use of footbridges and underpasses within reasonable walking distances from signalized crossings should be promoted by reducing pedestrian green time (Liang et al., 2020).

5.2.2 Transport infrastructure design practices

It is important to appraise any pedestrian facility improvement proposal based on scientific and objective grounds. In Hong Kong, standards and guidelines for pedestrian facilities such as pedestrian footpaths, crossing facilities, and pedestrian signals are stipulated in the Transport Planning and Design Manual (TPDM) published by the Transport Department (Lo et al., 2017). In assessing the need for footbridges or elevators, the conventional approach using existing pedestrian flow may not be indicative of a facility's potential usage. Before implementing the actual facility, appraisals, such as the addition of crossings, footbridges and elevators, can be evaluated based on the route choice model adopted in this paper.

5.2.3 Pedestrian accessibility and equity

The study of the impacts of socio-demographics on crossing behaviour is relevant because it reveals potentially disadvantaged subgroups. For example, younger adults (18 to 25 years old) are more willing to use underpass/footbridge routes, while older adults preferred the ordinary way of crossing (i.e., signalized at-grade crossing), even under poor weather conditions. Considering the significant effects of weather on the association between pedestrian crash severity and driver/pedestrian behaviour (Zhai et al., 2019), to promote equitable and safe walking environments, questions on how to encourage older individuals to use footbridges/underpasses are

important. A promising step could be installing elevators and movable staircases for footbridges/underpasses to make them more accessible to older adults (Chan et al., 2022a, 2022b), as they are more sensitive to accessible design and outdoor environments for the choice decision (Ojo et al., 2022), especially in neighbourhoods with older populations. Embedding not only spatial equity but also social equity in terms of walkability in transport and urban design is an essential step in promoting people-oriented and place-based paradigm shifts to promote walkable cities (Loo, 2021). This approach is also applicable to other developed societies that are facing the problem of an ageing population, such as the UK.

5.3 Limitations

Nevertheless, the current study suffers from several limitations. First, only four combinations of walking time for footbridges and underpasses are included in the SP experiment since the interdependency between extra walking times for footbridges and underpasses cannot be assessed, without controlling for the confounding factors including vertical difference, steepness of staircase and ramps, and presence and type of elevator. There is no general trend whether extra walking times for footbridges are higher than that for underpasses, and vice versa. Hence, there might be insufficient variation to capture the willingness to walk to footbridges and underpasses. Second, the basic assumption of this study is that all grade-separated crossing facilities are equipped with elevators. It is recognized that the footbridges and underpasses that have elevators are more preferred to those that do not have. Moreover, traffic speed is not included in the key attributes of the SP experiment, and it is possible that low traffic volume is associated with high traffic speed, which would be perceived as a risk factor by pedestrians. Furthermore, the question on income could be sensitive to some people with very high or very low incomes. Even that a “refuse to say” option was given in the questionnaire, some people may provide false information and distort the results. Finally, the sample distribution is not fully aligned with the population in Hong Kong; in particular, due to the limitation of the sampling method, the proportion of older people is inadequate. This could distort the results of parameter estimation for pedestrian choice behaviours.

For example, older people tend to be more risk-averse and sensitive to poor weather condition. Tendency using grade-separated crossing can be underestimated when older people is under-sampled. In future studies, it is recommended that the distribution of the sample be fully aligned with the population to provide more general and convincing results.

6. CONCLUSION

In this study, the influences of waiting time, walking time, traffic and weather conditions, and personal characteristics on the choice of crossing facility of pedestrians are examined using a stated choice experiment. The contributions of this study are twofold. First, trade-offs between the waiting time and walking time of different pedestrian groups are estimated, with which the moderation effects of weather conditions (i.e., rain and extreme hot weather) and crowdedness are considered. Second, a panel mixed multinomial logit model is established to measure the association using the random regret minimization approach, with which the effects of unobserved heterogeneity and panel data are accounted.

The results indicate that pedestrians' tendencies to use footbridges and underpasses are more sensitive to an increase in waiting time than to an increase in extra walking time. Reluctance to wait at a signalized crossing increases in adverse weather conditions, such as rain and extreme hot weather. In addition, traffic conditions and pedestrian volume affect pedestrian choices. Footbridges and underpasses with moderate pedestrian flow are preferred. Furthermore, gender and age group moderate the association between weather, traffic conditions, pedestrian volume, and the likelihood of using footbridges and underpasses. The results are indicative of the optimal design and planning of pedestrian facilities. Therefore, the use of footbridges and underpasses can be promoted, and traffic delays and pedestrian-vehicle conflicts at signalized crossings can be reduced (Hasan et al., 2020).

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1 Appendix

Section 1 Pedestrian perception: Which of the following best describes your “thought”?

Footbridge



1. Importance of different factor attributes

Do you think the following item is important for you to decide whether you would use the footbridge? (0 – the least important, 7– the most important)

0-----7

a) With elevator

0-----7

b) Familiarity

0-----7

c) Weather condition

0-----7

d) Temperature

2. Pedestrian preference

Following illustrations present different footbridge designs. Please rank the order based on your preference, from ‘the least preferred’ to ‘the most preferred’.

1) Elevator



Figure A. No elevator and no ramped walkway



Figure B. With ramped walkway



Figure C. With elevator



Figure D. With movable staircase

2) Presence and number of other pedestrians



	<p>Figure A. No other pedestrians</p>  <p>Figure B. Several pedestrians</p>  <p>Figure C. Many pedestrians</p>
<p>Signalized crossing</p> 	<p>3. Importance of different factor attributes</p> <p>Do you think the following item is important for you to decide whether you would use the signalized crossing? (0 – the least important, 7 – the most important)</p> <p>0-----7</p> <p>a) Length of the crossing</p> <p>0-----7</p> <p>c) Traffic condition</p> <p>0-----7</p>

d) Size of pedestrian island

4. Pedestrian preference

Following illustrations present different signalized crossings. Please rank the order based on your preference, from 'the least preferred' to 'the most preferred'.

1) Presence and width of pedestrian island



Figure A. No pedestrian island

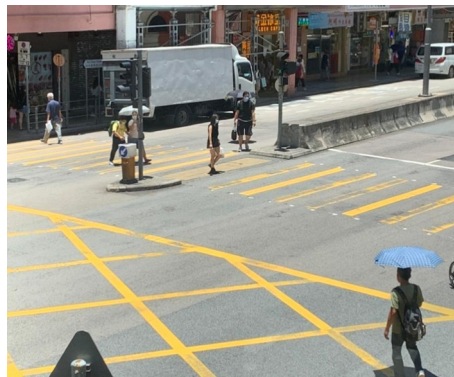


Figure B. Pedestrian island of 1 m wide



Figure C. Pedestrian island of 2 m wide

2) Traffic condition



Figure A. Low traffic



Figure B. Moderate traffic flow



Figure C. High traffic flow

	<p>3) Presence and number of other pedestrians</p>  <p>Figure A. No other pedestrians</p>  <p>Figure B. Several pedestrians are waiting at the kerbside of crossing</p>  <p>Figure C. Many pedestrians are waiting at the kerbside of crossing</p>
<p>Underpass</p>	<p>5. Importance of different factor attributes Do you think the following item is important for you to decide whether you would use the underpass? (0 – the least important, 7 – the most important)</p>



0-----7

a) Natural ventilation

0-----7

b) Artificial lighting

0-----7

c) Presence of other pedestrians

6. Pedestrian preference

Following illustrations present different underpasses. Please rank the order based on your preference, from 'the least preferred' to 'the most preferred'.

1) Elevator



Figure A. No elevator and no ramped walkway



Figure B. With ramped walkway



Figure C. With elevator

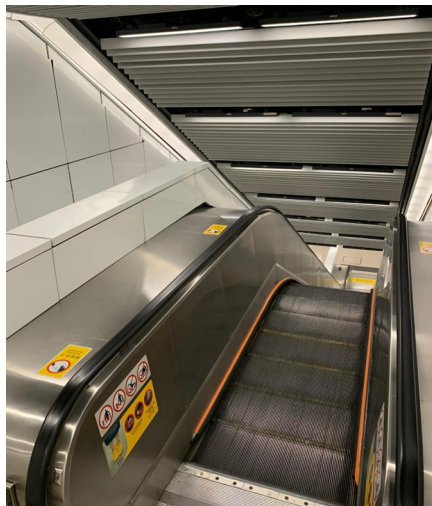


Figure D. With moveable staircase

5) Presence and number of other pedestrians



Figure A. No other pedestrians



Figure B. Several pedestrians



Figure C. Many pedestrians

1 **Figure A1. Preference of crossing facilities**

2

➤ Scenario 1

Now, you have arrived at the kerbside. Waiting time, walking time, and other conditions of available options are given in the Table below. Which option do you prefer?

	Option A: Signalized crossing	Option B: Footbridge	Option C: Underpass
Waiting time at A	30 seconds	0	0
Extra walking time for B and C	0	5 minutes	8 minutes
Traffic flow	Medium		
Pedestrian flow	Many pedestrians		
Weather	35°C, No raining		
Elevator	Not available		
	Available		



A



B



C

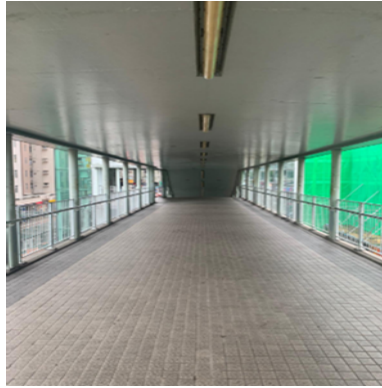
➤ Scenario 2

Now, you have arrived at the kerbside. Waiting time, walking time, and other conditions of available options are given in the Table below. Which option do you prefer?

	Option A: Signalized crossing	Option B: Footbridge	Option C: Underpass
Waiting time at A	30 seconds	0	0
Extra walking time for B and C	0	8 minutes	5 minutes
Traffic flow	Low		
Pedestrian flow	No other pedestrians		
Weather	28 °C, Raining		
Elevator	Not available		
	Available		



A



B



C

Figure A2. Stated choice experiment

1

2