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Age-proofing a traffic saturated metropolis – Evaluating the influences on walking behaviour in older adults in Ho Chi Minh City

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ABSTRACT

Walking is an essential mode of travel for older adults, offering significant health benefits. However walking as a travel mode in Vietnam is constrained by poor built environment quality and safety, which act as a psychological barrier to pedestrians in a traffic saturated environment. This study explores an extension of the Theory of Planned Behaviour (TPB) by incorporating built environment quality and safety constructs, along with proximity to destination types and vehicle availability indicators. A survey of active older adults (n = 832, aged 55 to 72) was designed and administered within four inner districts in Ho Chi Minh City (HCMC) to elicit socio-demographic, travel characteristics and psychometric data about past walking behaviour and future intention. A partial-least squares structural equation model (PLS-SEM) was used to conduct path and multi-group analyses (MGA) on main activity segments (retired, working at home and working outside), revealing statistically significant paths with satisfactory variance explained in a conceptual extended Theory of Planned Behaviour (eTPB) framework. The results show that intention to walk can be explained by past behaviour, with mediating effects from other factors, such as built environment and safety, via the standard TPB constructs (attitudes, subjective norms and perceived behavioural control). A clear relationship emerges between the factors examined, but with some exceptions and difference in MGA. This study demonstrates the importance of understanding older adults through examination of their main activity status. We also call for the development of travel behaviour and urban intervention programs to improve walking uptake and safety for older adults.

1. Introduction

With decreasing fertility rates and longer life expectancy, population ageing is an emerging challenge for both developing and developed societies worldwide. While emerging economies are benefiting from the demographic “windfall” of a large proportion of their population being of working age, it is expected the rate of ageing in these emerging economies will be more acute than in their developed counterparts (Pison, 2009). This is due to rapid industrialisation, rising child bearing costs, and in some cases, aggressive population control policies, such as the “one-or-two-child” policy in Vietnam (Goodkind, 1995). Some of these recently industrialising countries suffer from the phenomenon of “growing old before getting rich” (Huong et al., 2017). For instance, in Vietnam the number of people who are older than 65 years will grow rapidly from 12% in 2017 to 35% by the year 2050. This poses a significant challenge to the Vietnamese society due to a predicted shrinking labour pool and an increase in welfare and medical costs. While there are benefits in a reduction in overall travel demand, as older people tend to travel less (Zhao, 2014), declining physical health also increases the risk of accidents. With a reduction in incidental walking following retirement, other forms of walking, such as trips to shop and services, become more important. Differences in age and retirement status also influence travel behaviour (Barnes et al., 2016). Age-proofing transport by promoting more active travel and providing alternatives is already a significant policy and research focus in many developed societies (Fiedler, 2007). Public transport and active travel (such as walking) are of increasing importance for ageing populations, as driving become less feasible as health issues emerge (Dejoux et al., 2010; Mifsud et al., 2017). Older adults who engage in regular physical activity enjoy a range of physical and mental benefits - higher levels of physical activity may reduce, delay, or prevent the negative effects of chronic conditions, depressive illness, cognitive impairment and functional limitations

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(Cassarino and Setti, 2015; van den Berg et al., 2016). Built environments or social settings that do not promote active lifestyles lead to a vicious cycle of even less physical activity and more health problems (Keadle et al., 2016; Schrack et al., 2014). In car dependent societies, driving cessation in later life (Musselwhite and Shergold, 2013) may also cause social exclusion and transport disadvantage (Lange and Norman, 2018), especially in suburban environments where public transport is unreliable and walkability is low. Conversely, older people exhibit higher levels of mobility in transit-rich cities such as Hong Kong (He et al., 2018), but traffic-related accidents remain over-represented in older age groups in these cities (Loo and Tsui, 2016).

Research into transport for aged populations in developing countries and their cities which have saturated traffic is also emerging – with specific concerns about road hazards and inaccessible public transport and less walkability due to unfavourable built environments – heavy/mixed traffic and lack of walking/cycling paths (Ramachandran and D'Souza, 2016). Recent comprehensive reviews also highlighted the need to understand barriers to non-automobile modes for older people (Luiu et al., 2018), which may lead to tailor-made interventions and a paradigm shift in transport and land use planning (Stephenson et al., 2018). While the ageing of the population is beginning to be recognised as a looming threat in Vietnam (Ngo, 2013), there is limited research and specific policy development, especially on transport and the management of ageing mobilities. Ageing travel studies have rather been concentrated on highly developed Asian cities that are transit-based (Loo et al., 2017; Szeto et al., 2017) or in car-dependent urban settings such as in Australia or North America (Tuckett et al., 2018).

Research into ageing travel in traffic saturated developing countries is relatively sparse. Active travel research in Vietnam is currently focused on younger demographics (Leung and Le, 2019; Trang et al., 2012) despite evidence of reduced physical activity in those in the later stages of life (Trinh et al., 2008). Ubiquitous motorcycle use in Vietnamese cities also warrants specific policies and interventions. The case study city in this paper, Ho Chi Minh City (HCMC), is the largest city in Vietnam with a population of 8 million people, and this city is now experiencing rapid economic development. Similarly to this city's counterparts throughout South East Asia, motorcycle transport has become the dominant mode of travel, resulting in traffic saturated roads in many Vietnamese cities. Transport infrastructure investment, especially in public transport, is relatively underdeveloped compared with peer cities (Currie and De Gruyter, 2018). Furthermore, heavy mixed traffic poses a significant safety threat to older adults who use motorcycles, as their driving abilities decline. There has been previous research into the intention to use buses in HCMC to help develop mode shift interventions (Fujii and Van, 2009). To address these travel concerns for older people, this study sought to develop and extend frameworks to understand the barriers and motivations of older people and their engagement in active travel in Ho Chi Minh City (HCMC). This will help develop evidence-based environment development policies to target designs which could be successful in encouraging active travel.

2. Theoretical background and conceptual model

2.1. Travel behaviour research into active travel in older adults

Travel behaviour is shaped by complex interactions of spatial environment, socio-economic and personal factors (Van Acker et al., 2010). A wealth of theories and concepts that seek to explain travel behaviour have been postulated (Handy, 2005). Research into the walking (or active travel) behaviour of older adults usually refers to other age groups as well – but with a greater focus on declining health and different lifestyles. Table 1 outlines the notable studies involving older adult walking-related studies, with various designs, sampling sizes, and variables considered. Similar to general active research, two major streams can be identified: the first is the socio-ecological approach (Sallis et al., 2006) which takes a more environmentally-deterministic view – one would be more likely to partake in active travel if the conditions were favourable. On the other hand, psychology-based, or social-cognitive approaches, such as the Theory of Planned Behaviour (TPB) were applied to transport studies in order to understand personal and social influences on travel behaviour (Ajzen, 1991). TPB assumes behaviour is a reasoned decision determined by intention, which in turn is influenced by one's attitude towards the behaviour (in our case, the positive or negative evaluation of walking), subjective norm (the perceived social pressure or encouragement to walk), and perceived behavioural control (the effect of how easy or difficult it is to walk, or the limiting factors). There are also various metrics for walking in these studies with different purposes (walking as transport, recreation or exercise) or intensity (by frequency, duration or level of physical activity). As TPB is a socio-cognitive approach, there have been a number of studies (as shown in Table 1) which extended this by incorporating socio-ecological variables (such as built environment).

To evaluate walking behaviour or intention, simple regression, or more advanced statistical methods such as structural equation modelling (SEM), have been used. Prior studies have shown perceived behaviour control (PBC) to be an apt predictor of walking (Darker et al., 2010; Eves et al., 2003; Lee and Shepley, 2012). Attitude is also considered important for active travel (Beenackers et al., 2013). Some

Table 1
Selected studies on the walking outcome of older people.

Study	Location	Sample size and method	Socio-demographics	Built environment	TPB	Walking outcome
(Panter et al., 2011)	Norwich, UK	N = 1,279, Logistic regression	Age, gender, BMI, social class	Objective measures and perceived	Yes	Walking/cycling frequency to work, route length, habit strength index (7-item)
(Chang et al., 2014)	National survey, USA	N = 2,965, SEM	Age, gender, education, marital status, ethnicity	N/A	N/A but included social support/strain	Leisure activities (including walking)
(Wu et al., 2016)	Taiwan	N = 326, SEM	N/A	Perceived environmental characteristics (accessibility, aesthetics and safety)	Yes	Walking for exercise at least 3 times per week for 30 min each
(Ji et al., 2016)	Nanjing, China	N = 289, SEM	Age, gender, household composition, occupation, income	Built environment quality included as subjective norm	Yes	Time and distance of leisure activity. Ability to walk included as PBC.
(Lee, 2016)	Seongnam City, South Korea	N = 335, SEM	Age, gender, education, marital status, income, BMI	Perceived quality and safety	Yes	Walking frequency and duration
(Bird et al., 2018)	Cardiff, Kenilworth and Southampton, UK	N = 1796 (most aged over 50), multinomial logistic regression, longitudinal design, SEM	Age, gender, ethnicity, education, employment, income, number of cars in household	Visibility of active travel behaviour in the neighbourhood	Yes	Walking and cycling for transport and recreation, habit strength index (one item)

studies included past behaviour (Eves et al., 2003; Rhodes and Courneya, 2003) as well. The application of TPB may also help to better understand the determinants of travel, which in turn helps to design policies that create opportunities to overcome the barriers of active travel.

2.2. Conceptual framework and approach

A conceptual model was developed based on the literature reviewed in Table 1. To investigate the factors that contribute towards the walking behaviour and intention of older populations, this study extends the original TPB framework (Ajzen, 1991) by incorporating socio-ecological factors including built environment, destination proximity, number of vehicles available for use and past behaviour (Ajzen, 2011). In addition, the main activities of older adults are considered in multiple group analysis. The design for our paper considered Vietnamese local conditions and research feasibility, with the resultant conceptual model depicted in Fig. 1, denoting the direction of hypothesised relationships. The model is based on similar research that incorporated built environment quality and safety (Lee, 2016), but additional variables of past behaviour and number of vehicles are also considered.

Subsequently, a structural equation model (SEM) was developed to measure the constructs, and to test the pathways (or hypotheses) theorised in the conceptual model. While it is possible to examine the effects of different factors on walking behaviour with simpler regression methods, SEM is more advantageous in revealing the interaction among variables as it involves testing the relationship between the exogenous, mediator and endogenous variables. The study focuses on the comparison of how different socio-demographic groupings of older adults behave in their intention to walk. This also includes the assessment of path relationships across the subgroups of the surveyed results so as to determine the differences in multivariate effects in the model.

3. Methods

3.1. Partial least squares structural equation model (PLS-SEM)

The conceptual framework and survey data are analysed by partial least square structural equation modelling (PLS-SEM) using the *SmartPLS* software version 3.3.2 (Ringle et al., 2015). SEM techniques allow researchers to statistically examine interrelated dependence relationships between theory-derived latent constructs by measuring the indicator variables observed, in this case, by a survey. PLS-SEM has been proven to be a valuable tool for exploratory research (Sarstedt et al., 2014) and is suitable for more complex models (Richter et al., 2016).

In this study, we first assessed the measurement model, which evaluates the relationships between the survey variables observed and the theoretical concepts. Second, the structural model was tested by the PLS-SEM process, in which the causal relationships between the constructs as theorised in Section 2 were measured. PLS-SEM allows for the specification of constructs either as reflective or formative. In this study the TPB constructs were specified as reflective (i.e., the construct influences the indicator), and the extended Theory of Planned Behaviour (eTPB) constructs were specified as formative (i.e., the indicators influence the construct). The data can be segmented into groups for more specific analysis. Valid inter-group analysis requires measurement invariance, which refers to the same survey protocol measuring the same attributes across varying conditions (Horn and Mcardle, 1992), implying that neither the distinctive content nor meanings of latent variables cause dissimilarity across groups. Dissimilarity can lead to measurement error and misleading results. After assessment of the measurement and structural model, two non-parametric methods were used to conduct multi group analysis (MGA); Henseler's MGA (Henseler et al., 2009) and permutation (Chin and Dibbern, 2010). Before performing MGA, measurement invariance was assessed using the *measurement invariance of composites* (MICOM) approach using a permutation algorithm in *SmartPLS* (Henseler et al., 2016). Measurement invariance assessed by MICOM ensures the sampling results are not excessively different due to the varied interpretations of the respondents. This process provides the basis for meaningful comparison between groups and produces more

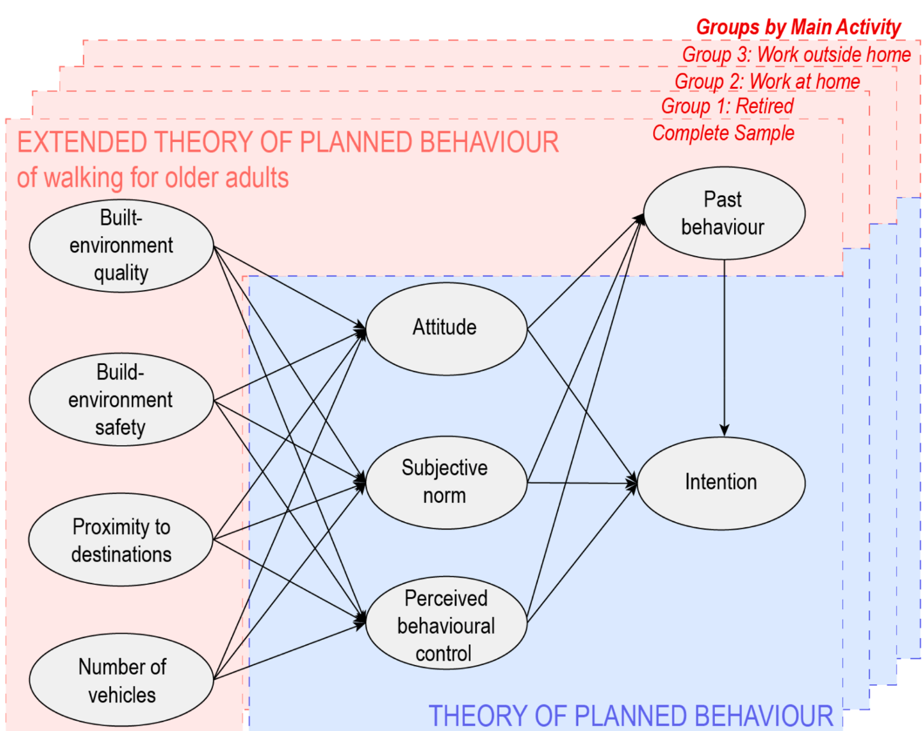

Fig. 1. Conceptual model of extended Theory of Planned Behaviour (eTPB) used in this study.

reliable MGA results.

4. Research design and survey

A face-to-face pen and pencil survey was conducted between November 2017 and March 2018 to gather data about the travel behaviour and perceptions of older adults. Four inner-city districts (District 1, District 3, District 4 and District 5) in HCMC were chosen for convenience sampling of residents living within or near these districts. Overall, these areas are more walkable than suburban counterparts within HCMC, and they are characterised by a high level of mixed-use and population density, however, many of these areas contain poorly built and maintained walking settings (Leung and Le, 2019). The surveys were administered in areas where older adults often frequent, such as traditional markets, educational/ recreation facilities, shopping plazas, and commercial districts, as shown in Fig. 2. The targeted respondents are those aged 55 or above (the general retirement age in Vietnam), residing within or near the study area districts. Out of 1972 survey attempts, 832 (42.2%) samples were considered valid for subsequent analysis.

The questionnaire includes three sections covering (1) socio-economic characteristics, (2) walking and travel behaviour questions, and (3) psychometric questions related to the extended TPB model. The constructs and questions were developed based on perceived built environment quality and safety, as outlined in detail in Table 2.

5. Results

5.1. Descriptive statistics

Table 3 shows the profile of respondents, separated by three groups of self-reported main activities of, 1) Retired and not working (hereafter referred to as *Retired*), 2) Actively working at home, including homemakers and self-employed persons (hereafter referred to as *Work at Home*), and 3) Working and regularly commuting outside usual residence (hereafter referred to as *Work Outside*). Means and standard deviation statistics of the item and constructs are provided in Supplementary File Table S2.

The usual mode questions relating to the five destination types in the survey revealed the travel characteristics of the respondents (for more details, see Supplementary File, Table S3). Five destination types were surveyed, including businesses (including working locations for both the respondents or for official business, such as government offices), traditional markets (*cho*), educational and recreation facilities (combined, as it is usual for elderly people to combine educational trips and recreational trips), large shopping plazas and more local, but smaller, convenience stores/shops. The purpose of the trip was not purposely surveyed - the trip's destination the trip is used to infer the purpose.

The results show that walking is the dominant travel mode for shopping trips to traditional markets or local shops, but less so for trips to large shopping centres, business and educational/recreational destinations. Public transport services in HCMC are not well received by older people, resulting in very low mode share for all destinations. This might be caused by the relatively high age (70 years old or over) eligibility for free public transport use in HCMC. The group differences are minor, but generally, those who do not report as retired are more likely to use motorcycles to travel to various destinations.

Another travel behaviour measure is the self-reported walking frequency during the last month. Future travel intention is measured by self-reported walking frequency for the next three months. Supplementary File, Table S4, outlines the descriptive statistics of these measures. There are some signs of past behaviour to intention gap - for the response "walk more than once a week" (the highest level of walking frequency), the indicated future intention is much higher than reported past behaviour.

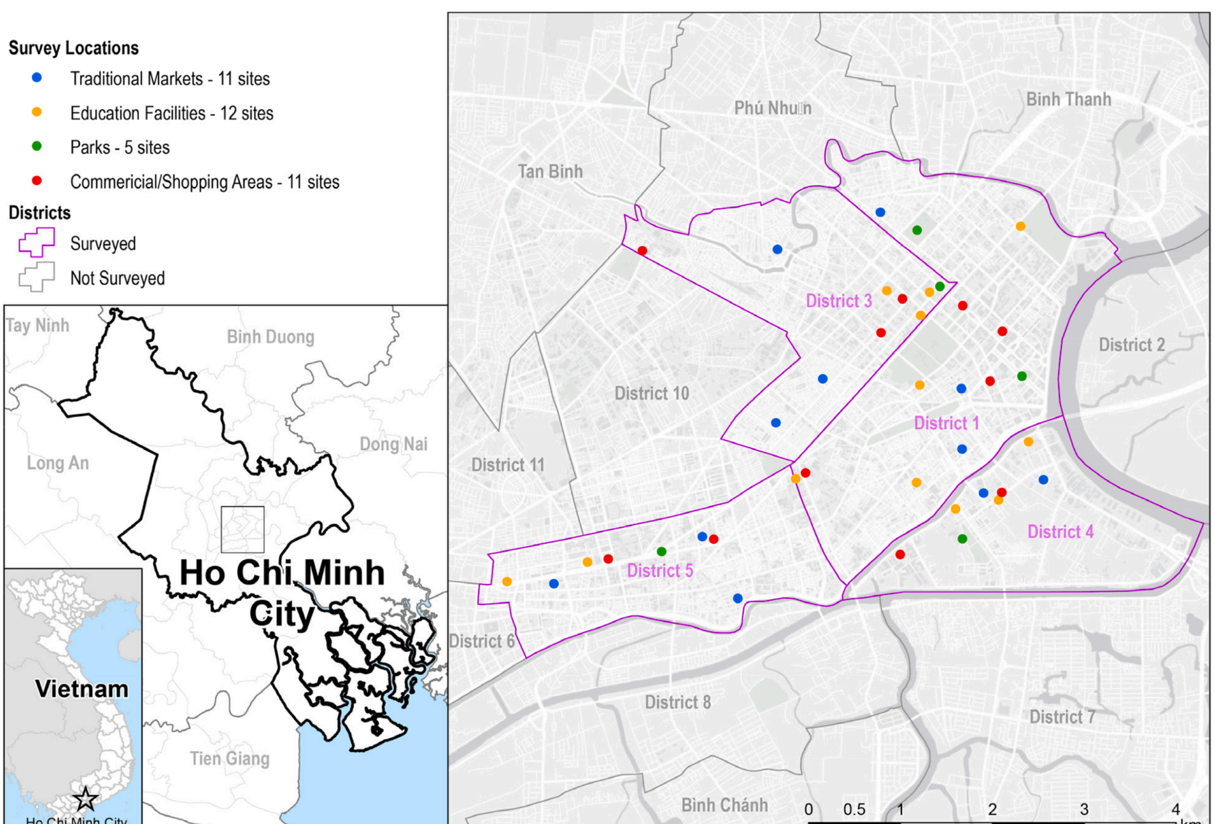

Fig. 2. Location of the survey locations and its districts (Detailed locations shown in Supplementary File, Table S1).

Table 2
Construct groups, measures and their response scale.

Construct	Item	Source	Response Scale
Perceived built environment quality (BEQ)	"Most of the green areas (parks) in my neighbourhood are easy to walk to" (BEQ1) "The walking routes in my neighbourhood are clean and tidy" (BEQ3) "The walking routes in my neighbourhood are well vegetated" (BEQ4)	(Cerin et al., 2013; Jia et al., 2018; Lee, 2016)	1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree (higher values mean better built environmental quality)
Perceived built environment safety (BES)	"Traffic in neighbourhood makes walking difficult or unpleasant" (BES1) "It is unsafe to walk due to traffic and risk of accidents" (BES2)	(Beenackers et al., 2013; Ferrer et al., 2015; Lee, 2016)	1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree (higher values mean less safe)
Proximity to Destinations (DES)	The number of destination types that are considered in proximity to the respondent's residence (i.e., reference of proximity is about 500 m or 10 min at a leisurely walking pace)	(Chudyk et al., 2015; Koohsari et al., 2014; Lee, 2016; Ribeiro et al., 2015)	Destination types include: 1) Businesses; 2) Traditional markets (*cho*); 3) Educational/ recreational; 4) Large shopping plazas; 5) Convenience stores/shops
Number of vehicles (NVH)	The number of vehicles at home, available for use to the respondent	(Chudyk et al., 2015)	Count
Attitude (ATT)	"I like walking as a way of travel" (ATT1) "Walking is beneficial to my wellbeing/health" (ATT2) "I find walking enjoyable usually" (ATT3) "When it is feasible, I prefer to walk instead of driving" (ATT4) "Walking is more convenient than driving as a way of travel" (ATT5)	(Gretebeck et al., 2007; Lee, 2016)	1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree
Subjective Norm (SN)	People who are important to me expect me to walk regularly (SN1) People who are important to me think I should walk more (SN2) People who are important to me support me to active travel (walk/bike) more (SN3) People who are important to me usually walk to their destinations (SN4)	(Gretebeck et al., 2007; Lee, 2016)	
Perceived Behavioural Control – General (PBC)	I am confident that if I wanted to, I could walk even when I am tired (PBC1) I am confident that if I wanted to, I could walk even under poor weather conditions (e.g., rain, wind) (PBC2) I am confident that if I wanted to, I could walk even when I don't have time (PBC3) I am confident that if I wanted to, I could walk even when I feel stressed (PBC4) I am confident that if I wanted to, I could walk even if there is no place to exercise nearby (PBC5) I am confident that if I wanted to, I could walk even when there is no one accompanying me (PBC6)	(Gretebeck et al., 2007; Lee, 2016)	
Perceived Behavioural Control – Safety (PBC-S)	I am confident about my knowledge of safe walking routes in my neighbourhood (PBC7) I am confident that I can walk safely in my neighbourhood (PBC8)	(Lee, 2016; Rahman et al., 2016)	
Past walking behaviour (PBH)	In the past month, how often have you walked from home to destinations nearby? (FQY)	(Lee, 2016)	1 = never; 2 = less than once a month; 3 = one to three times a month; 4 = about once per week; 5 = more than once a week
	The number of destination types where walking is the usual mode for the respondent (DWM, refer to Table S1 in Supplementary File)	(Verplanken et al., 1994)	Destination types same as DES (up to five)
Intention (to walk) (INT)	In the next three months, how often will you walk from home to destinations nearby?	(Lee, 2016)	1 = never; 2 = less than once a month; 3 = one to three times a month; 4 = about once per week; 5 = more than once a week

5.2. Measurement model

Tables 4 and 5 outline the reliability and validity indicators for the SEM model. The item outer loadings were greater than 0.7 in the full dataset model. The average variance extracted (AVE) was all greater than 0.5. Crombach alpha (CA) and composite reliability (CR) (Hair, 2017) were all very close or greater than 0.7. Discriminant validity was also assessed by Heterotrait–Monotrait ratio of correlations (HTMT),

Table 3
Respondents' profiles by main activity groups.

Item	*Retired (N = 427)*		*Work at Home (N = 216)*		*Work Outside (N = 189)*		Complete (N = 832)	
Sample size	427	(51.32%)	216	(25.96%)	189	(22.72%)	832	(100%)
Gender								
Male	176	(41.22%)	106	(49.07%)	120	(63.49%)	402	(48.32%)
Female	251	(58.78%)	110	(50.93%)	69	(36.51%)	430	(51.68%)
Age								
55–58	10	(2.34%)	0	(0%)	3	(1.59%)	13	(1.56%)
59–62	122	(28.57%)	67	(31.02%)	50	(26.46%)	239	(28.73%)
63–65	141	(33.02%)	85	(39.35%)	55	(29.1%)	281	(33.77%)
66–70	111	(26%)	37	(17.13%)	46	(24.34%)	194	(23.32%)
71–72	43	(10.07%)	27	(12.5%)	35	(18.52%)	105	(12.62%)
Number of vehicle(s) available for use								
1	156	(36.53%)	77	(35.65%)	69	(36.51%)	302	(36.3%)
2	132	(30.91%)	71	(32.87%)	62	(32.8%)	265	(31.85%)
Over 3	139	(32.55%)	68	(31.48%)	58	(30.69%)	265	(31.85%)
Total income (monthly, VND, including pension)								
Under 1 mil	37	(8.67%)	15	(6.94%)	17	(8.99%)	69	(8.29%)
2-7mil	174	(40.75%)	83	(38.43%)	73	(38.62%)	330	(39.66%)
8–13 mil	80	(18.74%)	54	(25%)	49	(25.93%)	183	(22%)
14–20 mil	76	(17.8%)	33	(15.28%)	27	(14.29%)	136	(16.35%)
Over 20 mil	60	(14.05%)	31	(14.35%)	23	(12.17%)	114	(13.7%)

Table 4
Measurement model for reflective constructs.

Construct	Indicator	Complete				Retired				Work at Home				Work Outside home			
		OL	α	CR	AVE	OL	α	CR	AVE	OL	α	CR	AVE	OL	α	CR	AVE
ATT	AT1	0.90	0.89	0.92	0.70	0.91	0.89	0.92	0.70	0.88	0.88	0.91	0.68	0.91	0.90	0.93	0.73
	AT2	0.84				0.83				0.82				0.88			
	AT3	0.79				0.81				0.80				0.73			
	AT4	0.77				0.76				0.74				0.82			
	AT5	0.89				0.87				0.89				0.92			
SN	SN1	0.81	0.86	0.90	0.70	0.83	0.86	0.90	0.70	0.79	0.83	0.89	0.66	0.78	0.87	0.91	0.72
	SN2	0.87				0.86				0.85				0.91			
	SN3	0.87				0.86				0.88				0.89			
	SN4	0.79				0.79				0.74				0.82			
PBC	PBC1	0.84	0.86	0.90	0.63	0.88	0.85	0.89	0.63	0.84	0.85	0.90	0.64	0.77	0.86	0.90	0.64
	PBC2	0.75				0.77				0.63				0.86			
	PBC4	0.82				0.77				0.84				0.88			
	PBC5	0.74				0.75				0.76				0.69			
	PBC6	0.83				0.80				0.90				0.78			
PBC-S	PBC7	0.87	0.69	0.87	0.77	0.88	0.68	0.86	0.76	0.86	0.70	0.87	0.77	0.87	0.71	0.87	0.78
	PBC8	0.88				0.87				0.89				0.89			

Abbreviations: OL = Outer loadings, α = Cronbach's alpha; CR = Composite reliability (D.G. rho); AVE = Average variance extracted.

Table 5
Measurement model for formative constructs.

Construct	Indicator	*Complete*			*Retired*			*Work at Home*			*Work Outside* home		
		VIF	OW	OL	VIF	OW	OL	VIF	OW	OL	VIF	OW	OL
BEQ	BEQ1	1.79	0.26	0.79	1.69	0.43	0.85	1.69	−0.10	0.58	2.29	0.36	0.88
	BEQ3	1.76	0.50	0.88	1.70	0.43	0.86	1.73	0.67	0.90	1.99	0.38	0.85
	BEQ4	1.50	0.44	0.83	1.43	0.35	0.77	1.57	0.54	0.85	1.67	0.43	0.85
BES	BES1	1.44	0.85	0.98	1.46	0.71	0.94	1.40	0.90	0.99	1.46	0.99	1.00
	BES2	1.44	0.24	0.71	1.46	0.42	0.81	1.40	0.16	0.65	1.46	0.03	0.58
PBH	FRQ	1.39	0.60	0.89	1.42	0.50	0.85	1.45	0.65	0.92	1.28	0.70	0.91
	UDE	1.39	0.55	0.86	1.42	0.63	0.91	1.45	0.49	0.85	1.28	0.46	0.79

Abbreviations: VIF = Variance inflation factor; OW = Outer Weights; OL = Outer loadings.

with none of the reflective constructs exceeding the recommended threshold of 0.85 (Henseler et al., 2015). For the formative constructs, there is no multi-collinearity issue between the construct items, as the variance inflation factors (VIF) were all below 3 (Kline, 2016). The formative constructs were considered valid as the outer loadings were above 0.5 (Hair, 2017). These results support further analysis using PLS-SEM.

5.3. *Structural model*

Based on the measurement model, the resultant structural model shows a good fit in terms of the standardised root mean square residual (SRMR) value for both the complete dataset and main activity groups of the structural model. This was under 0.08 as shown in Table 6, which satisfies the model goodness-of-fit requirements (Hair, 2017). The value is much improved in the eTPB model compared with the TPB model, only with ATT, SN, PBC and INT constructs.

Table 6
Model fit (SRMR) and explained variance (R^2) to outcome variables.

Model	Dataset	SRMR	Explained Variance (R^2) of Past Behaviour (PBH)	Explained Variance (R^2) of Intention (INT)
TPB	***Complete (n = 836)***	**0.068**		0.406
	Retired (n = 427)	0.073		0.363
	Work at Home (n = 216)	0.08		0.486
	Work Outside home (n = 189)	0.072		0.46
eTPB	***Complete (n = 836)***	**0.059**	0.47	0.548
	Retired (n = 427)	0.063	0.441	0.518
	Work at Home (n = 216)	0.063	0.602	0.628
	Work Outside home (n = 189)	0.073	0.475	0.577

The path coefficients for the *Complete*, *Retired*, *Work at Home* and *Work Outside* datasets are shown in Table 7 and are also graphically represented in Fig. 3 to 6. These figures indicate the causal relationships between constructs in a SEM model via the path coefficients of the complete dataset denoted by line thickness (higher values with thicker lines).

For the full sample, the strongest significant direct influence on walking intention was past behaviour (PBH) ($\beta = 0.49$, $p < 0.001$), followed by attitude (ATT) ($\beta = 0.22$, $p < 0.001$) and perceived behavioural control of safety (PBC-S) ($\beta = 0.21$, $p < 0.001$), and with weaker influences from overall perceived behavioural control (PBS) ($\beta = 0.11$, $p = 0.003$) and social norm (SN) ($\beta = 0.09$, $p < 0.001$). PBH was better influenced by the TPB constructs, with SN exhibiting strongest effects ($\beta = 0.31$, p ⟨001), followed by ATT ($\beta = 0.26$, $p < 0.001$), PBC ($\beta = 0.26$, $p = 0.001$) and PBC-S ($\beta = 0.21$, $p < 0.001$). For the eTPB constructs, built environment quality (BEQ) exerted stronger direct influences on the TPB constructs but had no effect on PBC-S. However, built environment safety (BES) produced a negative effect on PBC-S ($\beta =$ -0.12, $p < 0.022$), in which a higher BES value indicated that the respondent agreed that the built environment was not safe. The proximity of destinations produced a very strong effect on PBC-S ($\beta = 0.61$, $p < 0.001$) and to a lesser extent on PBC ($\beta = 0.15$, $p < 0.001$). The number of vehicles available to the respondent had a weak negative effect on ATT ($\beta =$ -0.07, $p < 0.035$). For the main activity groups, the effects were similar but with some nuanced differences. Notable effects were found for the *Retired* group, where NVH had greater negative effect than the total sample. For the *Work at Home* group, BEQ had a stronger effect on ATT, as did PBC to PBH, and PBC-S to INT. For *Work Outside*, SN had a particularly strong effect on PBH, and BES exerted greater influences on the TPB constructs (ATT, SN and PBC).

Measurement invariance across the group was established using the MICOM test (see Supplementary File Table S5 for the workings). This allows for multi-group analysis (MAG), which considers the effect of group differences, and compares the paths between group pairs. Group comparison with SEM can be considered advantageous over multiple linear regression in terms of the ability to assess complex structural models simultaneously (Sarstedt et al., 2011). In regression, groups or categorical variables are usually treated as dummy independent variables and are limited to one dependent variable at a time. Table 8 highlights the differences of path coefficient estimates in comparison pairs (*Retired* versus *Work at Home*; *Retired* versus *Work Outside* and *Work at Home* versus *Work Outside*), which indicates that several relationships are significantly different across the groups, as highlighted in grey, particularly the relationships between BEQ to ATT and ATT to PBH for *Work at Home* versus *Work Outside*. This implies those who were working at home were under greater influence from the built environment conditions than those who were working outside. Referring back to the usual mode responses and walking frequency (see Supplementary File, Tables S3 and S4), those who *Work at Home* were more likely to indicate walking as the usual mode in all the destination types queried. Built environment quality mediated via attitude are also important in explaining past walking behaviours. Similarly, safety was found more important for *Work at Home* than for the *Retired* in walking INT. Another set of significant differences was found between *Retired* versus *Work at*

Table 7
Results of the structural model (direct effect path estimates by bootstrapping).

Path estimates	Complete (n = 832)			*Retired* (n = 427)			*Work at Home* (n = 216)			*Work Outside* (n = 189)		
	β	t	p	β	t	p	β	t	p	β	t	p
BEQ → ATT	**0.22****	**2.78**	**0.005**	0.19	1.63	0.103	**0.41*****	**3.61**	**<0.001**	0.03	0.24	0.81
BEQ → SN	**0.32*****	**5.12**	**<0.001**	**0.38*****	**4.98**	**<0.001**	**0.28***	**2.3**	**0.021**	**0.28***	**2.27**	**0.024**
BEQ → PBC	**0.27*****	**4.74**	**<0.001**	**0.33*****	**4.01**	**<0.001**	**0.33****	**3.11**	**0.002**	0.15	1.26	0.208
BEQ → PBC-S	0.03	0.5	0.615	0.04	0.48	0.629	−0.07	0.79	0.432	0.06	0.6	0.549
BES → ATT	−0.04	0.52	0.603	−0.02	0.14	0.89	0.04	0.34	0.732	−0.2	1.78	0.075
BES → SN	−0.04	0.56	0.579	0.02	0.19	0.847	0.03	0.26	0.797	−0.21	1.71	0.088
BES → PBC	−0.04	0.62	0.536	0.02	0.28	0.782	0.05	0.47	0.642	**−0.21***	**2.07**	**0.038**
BES → PBC-S	**−0.12***	**2.29**	**0.022**	**−0.15***	**2.07**	**0.038**	−0.1	1.06	0.291	−0.12	1.18	0.238
DES → ATT	0.01	0.16	0.876	−0.02	0.42	0.676	−0.05	0.64	0.52	0.11	1.48	0.14
DES → SN	−0.01	0.35	0.724	−0.03	0.5	0.618	0.01	0.08	0.937	−0.02	0.28	0.779
DES → PBC	**0.15*****	**4.16**	**<0.001**	**0.11***	**2.13**	**0.033**	**0.22****	**3.05**	**0.002**	**0.17***	**2.14**	**0.032**
DES → PBC-S	**0.61*****	**22.57**	**<0.001**	**0.57*****	**14.17**	**<0.001**	**0.68*****	**14.48**	**<0.001**	**0.63*****	**11.19**	**<0.001**
NVH → ATT	**−0.07***	**2.11**	**0.035**	**−0.13****	**2.83**	**0.005**	no effect	no effect	0.997	−0.02	0.29	0.772
NVH → SN	−0.01	0.39	0.698	−0.02	0.52	0.602	0.01	0.11	0.91	−0.02	0.28	0.779
NVH → PBC	−0.02	0.52	0.601	−0.03	0.67	0.501	0.01	0.15	0.882	−0.02	0.25	0.8
NVH → PBC-S	0.02	0.76	0.45	0.01	0.28	0.78	0.08	1.67	0.095	−0.03	0.46	0.649
ATT → PBH	**0.26*****	**8.02**	**<0.001**	**0.26*****	**5.83**	**<0.001**	**0.33*****	**6.99**	**<0.001**	**0.15***	**2.23**	**0.026**
ATT → INT	**0.22*****	**6.72**	**<0.001**	**0.19*****	**4.34**	**<0.001**	**0.31*****	**4.36**	**<0.001**	**0.2****	**3.07**	**0.002**
SN → PBH	**0.31*****	**11.94**	**<0.001**	**0.34*****	**8.55**	**<0.001**	**0.18*****	**4.45**	**<0.001**	**0.45*****	**8.07**	**<0.001**
SN → INT	**0.09****	**3.43**	**0.001**	**0.08***	**1.97**	**0.049**	0.02	0.46	0.643	**0.17****	**2.84**	**0.005**
PBC → PBH	**0.26*****	**7.73**	**<0.001**	**0.21*****	**4.11**	**<0.001**	**0.44*****	**9.05**	**<0.001**	**0.15***	**2.12**	**0.034**
PBC → INT	**0.11****	**3.01**	**0.003**	**0.11***	**2.19**	**0.028**	0.03	0.35	0.729	**0.17***	**2.54**	**0.011**
PBC-S → PBH	**0.21*****	**7.67**	**<0.001**	**0.21*****	**5.59**	**<0.001**	**0.18****	**3.41**	**0.001**	**0.23*****	**4.18**	**<0.001**
PBC-S → INT	0.05	1.87	0.062	0	0.09	0.932	**0.14***	**2.53**	**0.012**	0.1	1.64	0.102
PBH → INT	**0.49*****	**8.93**	**<0.001**	**0.52*****	**6.97**	**<0.001**	**0.5*****	**3.86**	**<0.001**	**0.41*****	**3.99**	**<0.001**

*p < 0.05, **p < 0.01, ***p < 0.001. Grey highlighted rows contain significant direct effects in the complete sample, bold items indicate direct path with significant p-values.

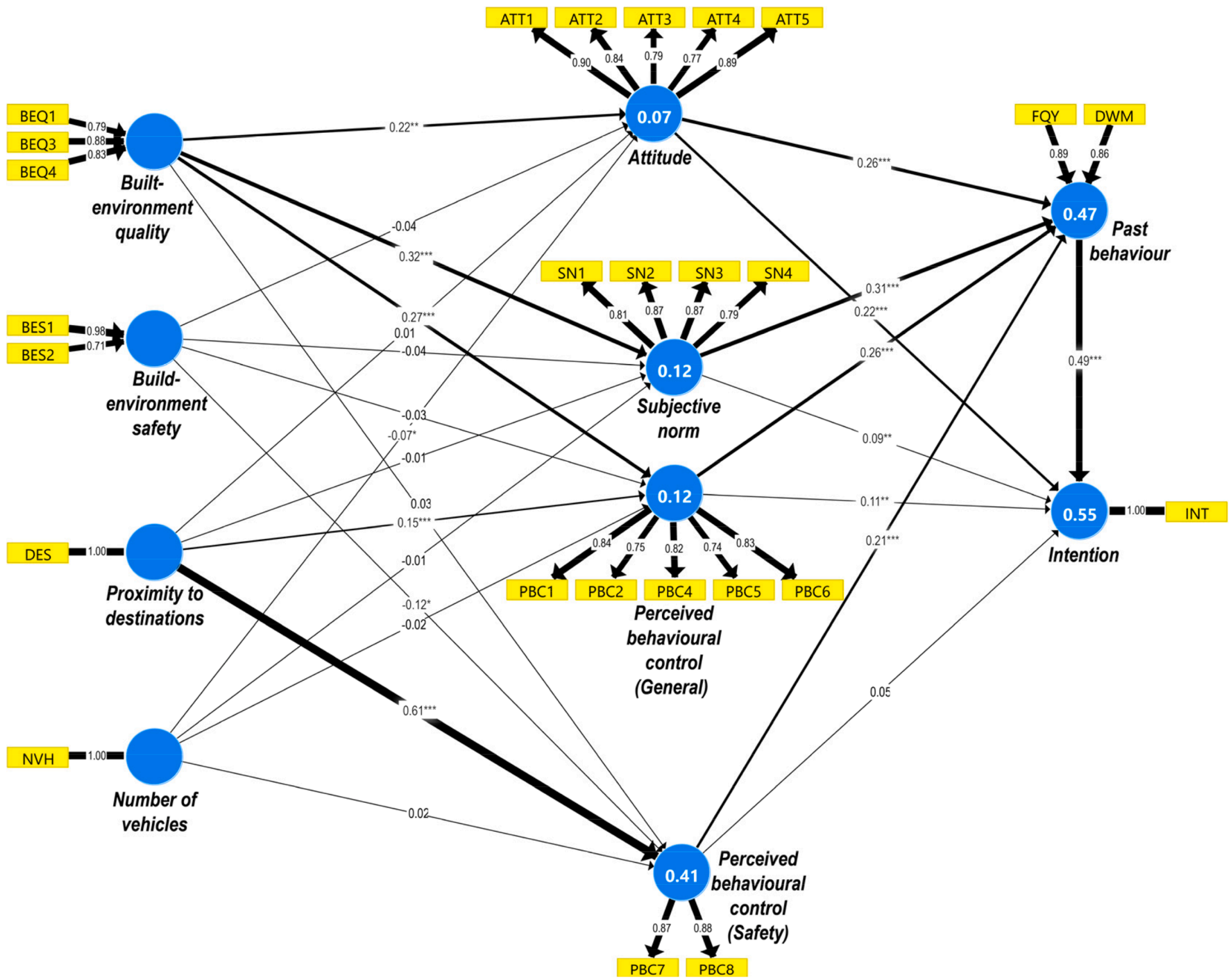

Fig. 3. Graphical representation of the structural model – Complete sample (n = 832).

Home and *Work at Home* versus *Work Outside* pairs. The influence of SN was stronger towards PBH for the *Retired*, but PBC was stronger for *Work at Home* in affecting PBH. Meanwhile, those who *Work Outside* were subjected to more social pressure (SN) in encouraging working than the *Work at Home* group, but external constraints, as indicated by PBC and attitude (ATT), were more important for those who *Work at Home* in influencing past walking behaviour.

The coefficient of determination (R^2) indicates the explained variance of the complete and group models. To estimate the significance of the path coefficient, bootstrapping was conducted using *SmartPLS* with a resampling value of 5,000. The R^2 of the complete dataset is also listed in a circle representing each construct in Fig. 3 (group specific R^2 iss provided in Supplementary File, Figs. S1 to S3). The constructs generally had good predictive power in model prediction. The eTRB model explained 47% of past walking behaviour in the complete sample, and 54.8% for future walking intention. The model is better in explaining the *Work at Home* group with over 60% explained variance for both outcome measures, followed by *Work Outside*, then the *Retired* group.

5.4. Mediation effects

Apart from direct effects, the SEM model also revealed the indirect and total effects which are mediated through the constructs, as shown in Table 9.

For the complete sample, the eTPB constructs of BEQ were stronger in exerting indirect and total effects towards PBH and INT than DES, which were both statistically significant. BES and NVH did not produce statistically significant indirect or total effects. For TPB constructs, statistically significant effects were found towards both PBH and INT. MGA also provides a statistical test for group differences: the TPC constructs of ATT, SN and PBC were found to have some statistically significant differences towards PBH or INT when comparing the *Retired* and *Work at Home* groups. There were also statistically significant differences when comparing *Work at Home* and *Work Outside* for the eTPB construct of BEQ and also the TPB constructs of ATT, SN and PBC. There was no significant difference found for the *Retired* versus *Work Outside* pair.

6. Discussion, limitations and further research opportunities

Generally speaking, this eTPB PLS-SEM study in Vietnam corroborates with previous research findings using TPB of built environment quality and safety to correlate with walking intention. We also confirm that vehicle availability exerts a slight negative effect towards walking intention (Chudyk et al., 2015; Manoj and Verma, 2015). Older adults with declining cognitive and physical ability are especially endangered by heavy traffic, particularly at road crossings (Loo and Tsui, 2016). Similar mixed traffic risks have been identified in comparably developing Indian cities with heavy mixed traffic conditions (Ramachandran

Table 8
Multi-group analysis comparing the three main activity groups.

Paths		*Retired* vs. *Work at Home*			*Retired* vs. *Work Outside*			*Work at Home* vs. *Work Outside*		
		p-value differences			p-value differences			p-value differences		
		Path Coefficient diff.	MGA	Perm.	Path Coefficient diff.	MGA	Perm.	Path Coefficient diff.	MGA	Perm.
H1a	BEQ → ATT	−0.22	0.18	0.242	0.16	0.392	0.44	**0.38**	**0.036***	**0.049***
H1b	BEQ → SN	0.11	0.454	0.447	0.10	0.49	0.497	−0.01	0.985	0.975
H1c	BEQ → PBC	−0.01	0.963	0.969	0.18	0.199	0.21	0.19	0.234	0.25
H1d	BEQ → PBC-S	0.11	0.36	0.404	−0.02	0.844	0.851	−0.13	0.337	0.372
H2a	BES → ATT	−0.06	0.722	0.771	0.18	0.243	0.325	0.24	0.148	0.173
H2b	BES → SN	−0.02	0.888	0.917	0.23	0.136	0.135	0.24	0.176	0.208
H2c	BES → PBC	−0.03	0.836	0.844	0.23	0.071	0.085	0.26	0.079	0.091
H2d	BES → PBC-S	−0.05	0.686	0.702	−0.04	0.771	0.764	0.01	0.921	0.925
H3a	DES → ATT	0.03	0.767	0.764	−0.13	0.141	0.126	−0.16	0.125	0.119
H3b	DES → SN	−0.03	0.727	0.732	0.00	0.963	0.966	0.03	0.798	0.811
H3c	DES → PBC	−0.12	0.184	0.181	−0.06	0.515	0.522	0.06	0.58	0.589
H3d	DES → PBC-S	−0.11	0.072	0.083	−0.06	0.372	0.395	0.05	0.458	0.469
H4a	NVH → ATT	−0.13	0.099	0.107	−0.11	0.19	0.192	0.02	0.826	0.837
H4b	NVH → SN	−0.03	0.697	0.695	0.00	0.966	0.966	0.03	0.776	0.779
H4c	NVH → PBC	−0.04	0.607	0.61	−0.01	0.867	0.883	0.03	0.777	0.77
H4d	NVH → PBC-S	−0.07	0.269	0.317	0.04	0.595	0.611	0.11	0.148	0.158
H5a	ATT → PBH	−0.07	0.262	0.349	0.11	0.196	0.214	**0.18**	**0.034***	**0.05**
H5b	ATT → INT	−0.12	0.164	0.173	0.00	0.996	0.989	0.11	0.229	0.236
H5c	SN → PBH	**0.16**	**0.006****	**0.013***	−0.11	0.103	0.112	**−0.27**	**<0.001*****	**<0.001*****
H6a	SN → INT	0.05	0.363	0.375	−0.09	0.175	0.173	**−0.15**	**0.046***	**0.041***
H6b	PBC → PBH	**−0.23**	**0.001****	**0.004****	0.06	0.538	0.552	**0.28**	**0.001****	**<0.001*****
H6c	PBC → INT	0.08	0.427	0.382	−0.06	0.488	0.512	−0.14	0.213	0.197
H7a	PBC-S → PBH	0.04	0.588	0.607	−0.02	0.801	0.79	−0.05	0.492	0.484
H7b	PBC-S → INT	**−0.14**	**0.038***	**0.045***	−0.10	0.166	0.187	0.04	0.595	0.611
H8	PBH → INT	0.02	0.934	0.909	0.11	0.378	0.416	0.09	0.554	0.562

(*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Grey highlighted rows indicate paths containing significant differences. Bold items indicate comparison with significant p-values, perm. refers to permutation.

and D'Souza, 2016). However, some of our TPB/e-TPB constructs may not be directly comparable to a similar study (Lee, 2016) on older adults' leisure-time walking in Korea with similar built environment quality and safety constructs. In our study for HCMC, past behaviour was included as a mediator for intention. Also, walking purpose was not specified, whereas, we put greater emphasis in unpacking the differences in the main activities of older adults via group analysis. In our case, descriptive and multi-group analyses revealed some significant differences in how past walking behaviour and future intention were formed.

One of the contributions of this study is empirical – this work adds to the research on walking behaviour in older adults in a developing country's inner-urban setting with high levels of mixed-use and density. In terms of methodological contributions, we extended the original TPB model by combining the original psychological and socio-cognitive constructs with external factors, including perceived built environment quality, safety, destination proximity, and also the number of vehicles available as an objective measure. PLS-SEM is used to explain individual walking behaviour of older adults in three main activity groups. The results show that SEM is useful in estimating the interrelated influences of walking-related variables. The findings of this study provide a theoretical contribution by expanding the research into the mobility of elderly people in developing cities. Our work provides further theoretical support for the predictive validity of the TPB in relation to walking behaviour. It also offers some evidence for the incremental validity of additional variables of the built environment (quality and safety), destination proximity and vehicle availability in the form of eTPB.

6.1. Policy implications and recommendations

There are a number of applied and policy implications in this study. First, the level of effects of the questions and the constructs could inform policymakers about the potential effectiveness of interventions to improve walking for older adults or even the general population (Darker et al., 2010). Based on our eTPB measures, it is found that walkable and safe neighbourhoods could help create positive attitudes towards walking. However, in HCMC, active streets are largely limited in the city centre. As the BEQ construct is important in influencing walking intention of older adults, improving the streetscape with better pedestrian design and management (e.g., cleaning and repairs) needs to be carried out in HCMC. Also, generous provision of vegetation can serve as shading, which is particularly important in hot and humid climates. From the BES construct, improving safety by providing better crossings and interactions to protect vulnerable older adults is also vital, but traffic conditions are usually chaotic and risky for pedestrians in HCMC. Yet there are some advantages in the existing strong mixed-use patterns and relatively high urban density as indicated by the DES construct. This helps to facilitate more destinations which are situated close to the residences of the elderly.

Our segmented approach using MGA for PLS-SEM in analysing walking determinants also demonstrates that older adults are not a homogenous group. Different people have different needs based on their level of health, location of residence and travel preferences and needs. Transport and planning policy should also be adaptive and encompassing. Community participation in better age-friendly urban and transport planning is also imperative to facilitate a better walking environment. Tuckett et al. (2018) advocated a "Discover-Discuss-Activate-Change" approach to help identify issues and facilitate meaningful community change. Local authorities in Vietnam should also consider adopting such approaches.

6.2. Limitations and future research opportunities

A limitation of this study is that it was constrained by research budget and resources. We were unable to examine a large sample or to conduct stratified sampling, or to expand into suburban areas for comparison. Convenience sampling limits the generalisability of this study's findings as the respondents are from better socio-economic backgrounds, therefore the results should be interpreted with some caution. This study was intended to be exploratory; we did not plan for longitudinal designs that allow for comparison of past intentions with future behaviour (Bird et al., 2018; Mertens et al., 2019) or to examine whether

Table 9
Indirect and total effects for complete sample and group differences.

Complete (n = 832)								
Origin Constructs	Indirect Effects β		Total Effects β					
	PBH	INT	ATT	SN	PBC	PBC_S	PBH	INT
BEQ	0.232***	0.221***	0.219**	0.319***	0.27***	0.026	0.232***	0.221***
BES	−0.054	−0.048	−0.039	−0.035	−0.035	−0.116*	−0.054	−0.048
DES	0.163***	0.129***	0.006	−0.013	0.152***	0.605***	0.163***	0.129***
NVH	−0.023	−0.029	−0.071*	−0.013	−0.018	0.021	−0.023	−0.029
ATT		0.125***					0.259***	0.349***
SN		0.152***					0.313***	0.238***
PBC		0.126***					0.26***	0.237***
PBC-S		0.101***					0.208***	0.155***
PBH								0.485***
Group differences: *Retired* vs *Work at Home*								
BEQ	−0.064	−0.058	−0.219	0.108	−0.006	0.109	−0.064	−0.058
BES	−0.049	−0.025	−0.057	−0.016	−0.026	−0.049	−0.049	−0.025
DES	−0.075	−0.117	0.026	−0.031	−0.118	−0.112	−0.075	−0.117
NVH	−0.066	−0.077	−0.132	−0.032	−0.041	−0.07	−0.066	−0.077
ATT		−0.032					−0.073	−0.147*
SN		0.084*					0.155**	0.137*
PBC		−0.111					−0.227**	−0.03
PBC-S		0.021					0.035	−0.119
PBH								0.017
Group differences: *Retired* vs *Work Outside*								
BEQ	0.087	0.081	0.156	0.102	0.18	−0.024	0.087	0.081
BES	0.158	0.184	0.182	0.227	0.234	−0.036	0.158	0.184
DES	−0.049	−0.108	−0.134	−0.004	−0.059	−0.059	−0.049	−0.108
NVH	−0.025	−0.034	−0.111	−0.004	−0.013	0.037	−0.025	−0.034
ATT		0.072					0.106	0.071
SN		−0.008					−0.111	−0.102
PBC		0.046					0.055	−0.013
PBC-S		0.016					−0.018	−0.082
PBH								0.111
Group differences: *Work at Home* vs *Work Outside*								
BEQ	0.151	0.139	0.375*	−0.007	0.186	−0.132	0.151	0.139
BES	0.207	0.209	0.24	0.243	0.26	0.013	0.207	0.209
DES	0.026	0.009	−0.16	0.027	0.059	0.053	0.026	0.009
NVH	0.041	0.043	0.021	0.028	0.027	0.107	0.041	0.043
ATT		0.104					0.179*	0.218*
SN		−0.092					−0.266***	−0.239**
PBC		0.156*					0.282**	0.016
PBC-S		−0.005					−0.053	0.037
PBH								0.093

*p < 0.05, **p < 0.01, ***p < 0.001. Grey highlighted rows indicate paths contained significant effects or differences.

intention changes over time (Conner and Godin, 2007). Controlled studies that evaluate the effects of interventions (such as neighbourhood improvement or travel behaviour programs) are also welcomed for future research. Understanding past behaviour in terms of habit could also be a welcome addition for studies of this kind (Verplanken et al., 1994). In addition to frequency and destination where walking is the main mode, specifying the length of walking time (Williams and French, 2014) and more detailed trip purpose could also be practiced. But there are issues in the accuracy of self-reporting, considering older people's abilities to recall.

Another methodological deficiency of this work is the reliance of Likert scales to quantify psychological constructs. This may not capture the full extent of perceptions, views and comments. Qualitative approaches such as interviews (Burnett and Lucas, 2010) or observations of urban environment (Almeida, 2016) should also be considered. The current study relied on user-reported evaluation of built environment quality and safety. More objective approaches could be incorporated in future research, such as the microscale walkability assessment, accounting for elements including pedestrian safety, comfort, and convenience developed by Loo and Lam (2012). Further, measuring or tracking walking trips is also useful in measuring actual walking behaviour (Cerin et al., 2011), which may help address issues of self-reporting. Built environment metrics measured objectively may also offer a useful comparison with self-rated perceptions (Panter et al., 2011; Troped et al., 2017). Another possible extension is to understand how travel relates to satisfaction in older populations – does the ability to walk in the neighbourhood makes one more satisfied? (Lättman et al., 2019). Apart from these limitations, this study is able to meet the objectives in establishing the relationships between socio-demographic, built-environment and individual psychological factors that contribute to the walking behaviour of older adults in the main activity groups of *Retired*, *Work at Home* and *Work Outside*.

CRediT authorship contribution statement

Thi Phuong Linh Le: Writing - original draft, Conceptualization, Investigation, Data curation, Software, Validation. **Abraham Leung:** Conceptualization, Writing - review & editing, Methodology, Visualization, Validation. **Ilya Kavalchuk:** Writing - review & editing, Supervision, Funding acquisition, Resources. **Hoang Nam Nguyen:** Conceptualization, Investigation, Data curation, Project administration.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tbs.2020.10.008.

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