Destination Accessibility and Walking for Different Purposes in Older Adults

by

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DECLARATION

This thesis contains no material that has been extracted in whole or in part from a thesis that I have submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgement in the main text of the thesis.

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where required).

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LIST OF ABBREVIATIONS AND THEIR DEFINITION

ACU	Australian Catholic University
PA	Physical Activity
LCA	Latent Class Analysis
LPA	Latent Profile Analysis
GEE	Generalised Estimating Equation
ZINB	Zero-Inflated Negative Binomial
GLM	Generalised Linear Model
HABITAT	**H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and Ac**T**ivity
CI	Confidence Internal
OR	Odds Ratio
SD	Standard Deviation
ABS	Australian Bureau of Statistics
NEWS	Neighbourhood Environment Walkability Scale
NEWS-CS	Neighbourhood Environment Walkability Scale for Chinese Seniors
NWQ-CS	Neighborhood Walking Questionnaire- Chinese version for Seniors
IPAQ	International Physical Activity Questionnaire
WHO	World Health Organisation
SES	Socio-Economic Status
NSES	Neighbourhood-level Socio-Economic Status
ABS	Australian Bureau of Statistics
HK	Hong Kong
JAPA	Journal of Aging and Physical Activity
NHMRC	National Health and Medical Research Council
EHCs	Elderly Health Centres

IPEN	International Physical Activity and Environment Network
SEIFA	Socio-Economic Indexes for Areas

ABSTRACT

Abstract

ABSTRACT

Background: This thesis examined the associations between perceived destination accessibility of 12 types of destinations (*supermarket, café/restaurant, fruit and vegetable shop, fast food restaurant, public transport, public park, post office, library, primary school, childcare centre, chemist/drug store and doctor/medical centres)* within a 5-, 10- and 20-minute walk from home and self-report measures of walking for transport and recreation in older adults (people aged 65 years or older) residing in Brisbane, Australia and Hong Kong, China. The overall objective of this thesis was to investigate and compare the relationships of perceived destination accessibility in the neighbourhood with walking for transport and recreation in older adults living in low- and high-density urban environments. The overall thesis objective was divided into three principal aims and each aim was addressed by an empirical study with distinct rationales, aims and statistical methods. *Study One* addressed the first principal aim of the thesis. The primary aim of this study was to characterise perceived destination accessibility within a 5-, 10- and 20-minute walk from home in the two cities and examine between-city differences in perceived access to specific destinations and mixes of destinations. *Study Two* addressed the second principal aim. This study extended the findings from Study One by examining associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and self-report measures of total (location non-specific) walking for transport and recreation in older adults residing in the two cities. Further, this study examined associations of perceived destination accessibility with self-report measures of within-neighbourhood walking for transport and recreation in older adults within the context of Hong Kong. *Study Three* investigated the third principal aim of the thesis. This study extended the findings from Study One and Study Two by examining the moderating effects of nine perceived neighbourhood non-destination characteristics (*physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic*

hazards; traffic speed; safety from crime; sitting facilities; and presence of bridges/overpass) on associations of perceived destination accessibility within a 5-, 10- and 20-minute walk from home with self-report measures of walking for transport and recreation in older adults within the context of Hong Kong.

Methods: This thesis used data from two extant epidemiological studies on environmental correlates of physical activity conducted in Brisbane (N= 793) and Hong Kong (N= 484) with comparable measures of 12 perceived destination accessibility and self-report measures of walking for different purposes. The Brisbane data came from the *Wave 3 (2011)* of a multilevel longitudinal study—the **H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and Ac**T**ivity (HABITAT)—among adults of 45-70 years in Brisbane (conducted in 2007-2011), while the Hong Kong data came from a cross-sectional study (the Hong Kong Elderly Study) among older adults in Hong Kong (conducted in 2007-2008). The two studies were based on the socio-ecological framework of health behaviour and used similar sampling strategies —that is, older adults nested within neighbourhood environments varying in environmental characteristics — that maximise the variability in exposures within the study sites. A range of analytical techniques were used to address the thesis aims, including a variable-centred approach (advanced regression models) and a person-centred approach (latent class/profile analysis). All models were adjusted to account for neighbourhood-level clustering arising from the two-stage sampling design. Stata 15.1 was used to perform the regression and moderation analyses, while Mplus 7.4 and 8.0 were used to perform latent class and latent profile analyses respectively.

Results: The findings suggest that older adults living in Hong Kong perceived higher levels of destination accessibility within a 5-, 10- and 20-minute walk from home than older adults

in Brisbane. City-specific latent structures of perceived destination accessibility varied between the two cities and also influenced walking behaviours in older adults. Further, perceived neighbourhood non-destination characteristics independently or conjointly moderated the destination-walking relationships in older adults within the context of Hong Kong.

Conclusion: This thesis suggests that providing neighbourhoods with higher levels of destination accessibility can help encourage walking for different purposes, especially walking for transport in older adults. However, other perceived neighbourhood non-destination characteristics such as safety from crime, sitting facilities, pedestrian infrastructures, connectivity, aesthetics and the presence of people in the street can moderate destination-walking associations.

KEYWORDS: Perceived destination accessibility, latent class analysis, latent profile analysis, walking for transport and recreation, moderating effects, environmental moderators.

CHAPTER 1

INTRODUCTION AND OVERVIEW

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 Background: Ageing population—Demographic trends

Globally, the population is ageing as a result of declines in fertility rates and longevity, with the proportion of older adults (≥ 65 years old) rising faster than all other age groups [1-4]. By 2050, the global population of older adults will be 1.6 billion, constituting 16.7 percent of the overall global population of 9.4 billion [2]. This projection is equivalent to an annual average increment of 27.1 million older adults from 2015 to 2050 [2], with the vast majority of the predicted increase emerging from the developing countries [2, 4]. The projection varies substantially across genders, race/ethnic groups, socioeconomic status (SES) groups [5] and geographical region [6]. Thus, Africa, East Asia, Southeast Asia and Latin America will experience extraordinarily rapid increases equivalent to 3% - 4% annually [7]. This is especially the case for countries such as Brazil, China, India, Indonesia, South Korea and Thailand [7].

The estimated increase in the proportion of older adults within the global population may have positive and negative implications for our societies. Positive effects pertain to the fact that the younger generation may gain wisdom, experience, guidance, cultural and traditional values from the older generation, while the negative impact refers to the fact that the estimated increase in older adults may have detrimental effects on the public health, healthcare sector, social services and economic growth [8-10]. The negative effect may arise due to ageing being a complex process characterised by several challenges such as frailty [11], functional limitations [12-16], and various chronic health conditions, such as cardiovascular diseases, osteoporosis and cancer [17-20]. Evidence suggests that biological, behavioural, cultural and environmental factors all contribute to people's health and well-being [21-27]. One of the main behavioural factors that contribute to individuals' health outcomes and well-being is regular engagement in physical activity (PA) [4].

1.1.1 Levels of physical activity and public health implications

Empirical evidence suggests that regular engagement in at least 150 weekly minutes of moderate-to-vigorous intensity PA contributes positively to numerous health outcomes [4, 28]. Sufficient levels of PA have been shown to improve cognitive health [29, 30] and lower depressive symptoms [31], mortality rates, comorbidity [28, 32], and the incidence of cardiovascular diseases and some cancers [33]. Consequently, many countries and several institutions, such as public health organisations, social and health services, have employed PA as an effective and robust strategy to help prevent, delay or manage several major non-communicable chronic diseases (NCDs), including cardiovascular diseases, type 2 diabetes, osteoporosis, cognitive impairment and some cancers in people [4, 34-40]. Despite the numerous health benefits associated with regular engagement in PA, available evidence suggests that older adults are the least physically active age category [4]. This suggests that creating opportunities to help older adults engage in a physically active lifestyle is important.

PA behaviours can be categorised into four major domains: occupation-related activities, household activities, transport-related activities and recreational or leisure-time related activities [4, 41]. PA can also be described in terms of type (e.g., walking, running, swimming), frequency (e.g., number of PA bouts per week), intensity (based on estimates of energy expenditure by unit of time) and duration (e.g., measured in minutes or hours of engagement in single bouts of PA) [4]. In public health research, PA intensity is usually categorised as light, moderate or vigorous [4]. PA intensity is defined in terms of the energy expenditure level, usually expressed as the Metabolic Equivalent (METs) value of an activity [4]. METs represent the ratio of an individuals' working metabolic rate relative to their resting metabolic rate [42]. Thus, one MET is equivalent to the amount of oxygen or energy utilised by a person's body while resting [42]. That is, one MET equals a person's resting metabolic rate (energy expenditure spent while sitting quietly) and corresponds to the use of

3.5 ml of oxygen per kilogram of body weight [42, 43]. Although the health benefits of regular participation in PA can be different at different intensities, regular engagement in moderate-intensity PA (requiring 3.0-5.9 METs) yields similar health benefits to engagement in vigorous-intensity PA (requiring at least 6.0 METs) in older adults [4]. For this reason, the WHO has recommended that public health initiatives targeting older adults should focus on moderate-intensity activity such as walking as an intervention strategy because of the lower risk of musculoskeletal injuries associated with it compared to vigorous-intensity PA [4].

1.1.2 Walking as a moderate-intensity physical activity behaviour

Walking, whether for transport (e.g., walking to or from a place within a neighbourhood) or for recreation (walking for the purpose of leisure or exercise, such as walking a pet), is the most common form of PA [4, 40]. Walking has been identified globally as a robust public health strategy to increase PA levels in people, particularly in older adults [4, 44]. This is because walking has been shown to benefit numerous health outcomes. Regular participation in walking at moderate-intensity can lower the incidence of cardiovascular diseases and some cancers [33], improve cognitive health [29, 30], lower depressive symptoms [31] and reduce mortality rate [32].

Empirical evidence suggests that walking for transport is associated with numerous health benefits [45, 46], such as reduction in cardiovascular risk [47], a higher level of cardiorespiratory fitness and improved functional health and independence [4, 48]. Additionally, walking for transport has environmental benefits, such as reductions in vehicular traffic congestion on roads [49-51], air pollutants (e.g., carbon dioxide gas emission, nitrogen oxides and hydrocarbons) [46, 50] and noise pollution [48]. Walking for transport is also associated with increased neighbourhood liveability and social inclusiveness

[48]. The need to replace short motorised trips with walking is widely accepted and promoted in many developed countries [4, 52, 53].

Walking for recreation is the most popular form of leisure-time PA in older adults across geographic regions [48, 54, 55]. In Australia, 45.6% of older adults reported having engaged in recreational walking each week [56] and 42.0% of older people in Victoria, Australia, reported walking for recreation over 150 minutes per week [48]. Over a quarter of a sample of older adults from three central European countries (the Czech Republic, Slovakia and Poland) met recommended levels of recreational walking [57]. In Brazil, 34.5% of older adults have been found to walk for recreation for at least 10 minutes per week [58]. Encouraging older adults to be physically active through walking for transport and recreation can benefit their health [4]. Providing an environment with features supporting walking may be one way to achieve this [59, 60]. Evidence suggests that the neighbourhood environment has the potential to influence older adults' walking behaviour [53, 61, 62].

1.1.3 The neighbourhood environment, destination accessibility and walking in old age

Several health-related behaviour change theories, such as the health belief model (HBM) [63], social learning theory [64-66] and the theory of planned behaviour [67] have been previously employed to guide interventions promoting healthy behaviours in older adults, including PA and walking. These health-related models are primarily focused on individual-level determinants of behaviour change [68, 69] and, target factors that would unlikely lead to large-scale and sustainable effects [70]. For these reasons, interventions based on these models have had a minimal impact at the population level [70, 71]. In the last decade, investigators have identified the importance of environmental factors in relation to PA behaviour [72]. This is because environmental interventions can potentially affect a large number of people (i.e., populations) for a sustained period of time [4].

The context in which people live, work, play and interact plays a significant role in determining their PA behaviour, health outcomes and well-being [73-77]. Due to retirement, ageing-related physical functional limitations and loss of independence [4, 15], older adults are likely to spend more time in their local neighbourhood than younger age groups [78, 79]. It is, therefore, not surprising that empirical evidence suggests that the characteristics of the neighbourhood environment have the potential to influence older adults' walking behaviour [4, 44, 53, 61, 62] and health [9]. Older adults are exposed to characteristics of their neighbourhood environment and such exposure can influence their walking behaviour directly or via the interaction with other influences [10, 76, 80-84].

The neighbourhood environment consists of physical (built) and social features [75]. Examples of features of the built environment include footpaths and destinations such as shops, hospitals, restaurants, public transport stops and public parks, while features of the social environment include safety from crime, social cohesion, the presence of people in the street and social networks [75]. These features may serve as facilitators or barriers to older adults' tendencies to engage in walking for transport or recreation as older adults are more sensitive to the physical features of the neighbourhood environment than younger adults [4, 44, 53, 61, 62].

Destination accessibility is a key neighbourhood built environment feature that has been shown to influence walking behaviour in older adults [53, 85]. That is, neighbourhoods with high destination accessibility within a short walking distance from home encourage more walking than those with low access to destinations [53]. Access to destinations can be defined as the interaction between individual- and neighbourhood-level characteristics [80, 86, 87]. More specifically, neighbourhood destination accessibility can be defined as the availability of destinations such as shops, public transport stops and hospitals within walking

distance from home, and the ease of reaching them by any means of transport (e.g., by walking and/or public transport or by a private vehicle) [80, 86, 87].

Destination accessibility can be quantified objectively or via self-reports [53]. Although there is a mismatch between objective and self-report measures [88], self-report measures may be more appropriate when assessing neighbourhood destination accessibility in older adults [53]. This is because older adults' populations are heterogeneous regarding their level of mobility and physical capacity [12, 89]. For example, even within the same neighbourhood, individuals may report different levels of accessibility to a particular destination (e.g., access to the supermarket) based on their physical capacity and perceptions of other environmental factors (e.g., presence of footpaths or traffic safety) [90, 91]. Hence, this PhD research program focused on perceived neighbourhood environmental characteristics (destinations accessibility and other neighbourhood characteristics) as correlates of older adults' walking behaviour in different geographical contexts to help inform global and local policies that may impact on older adults' PA.

1.2 Theoretical framework of the PhD research program

Based on the current literature, a conceptual framework (Figure 1) underpinning this PhD research program has been developed. It is based on Sallis et al.'s [68] socio-ecological model, and on conceptual frameworks proposed by Cerin et al. [53] and Giles-Corti et al. [92]. According to this framework, older adults' walking behaviours are influenced by their perceptions of accessibility of different types of destinations (destination mixes) in the neighbourhood. The higher the level of perceived accessibility to various destinations, the more likely older adults are to engage in walking for transport and/or recreation. Moreover, according to the proposed theoretical framework presented in Figure 1, the strength of the associations between perceived destination accessibility and walking outcomes is likely to

depend on older adults' perceived neighbourhood safety, aesthetics and pedestrian infrastructure (as single moderators and combined profiles of moderators).

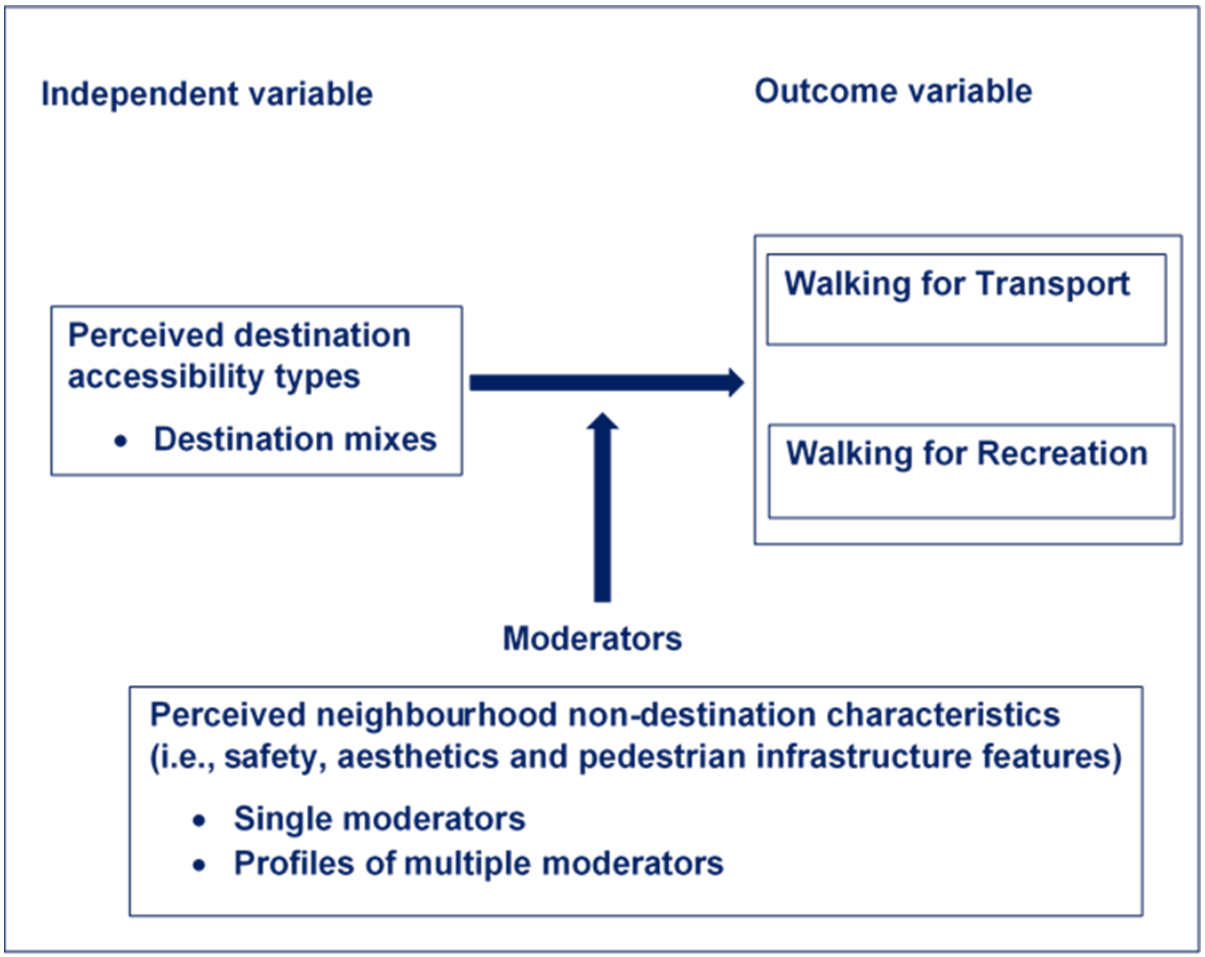


Fig 1: Theoretical framework of the PhD research program

1.3 Research program rationale and aims

Although research on the relationships between destination accessibility and walking outcomes in older adults is growing, the available evidence is not consistent. Discrepant findings may be in part due to between-study differences in the levels, variability and profiles of destination accessibility (i.e., mixes of types of destinations available within neighbourhoods). In addition, previous research attempted to examine the multilevel and multidimensional relationships between destination accessibility and walking using

unidimensional or bivariate analytical approaches, and the majority of these studies were conducted in a single geographical location with limited variability in environmental exposures [53, 61, 62]. As such, these studies might have been unpowered to detect consistent associations between environmental exposures and PA outcomes.

To address the above-mentioned limitations of previous research, this PhD research program examined differences in walking behaviours and perceived destination accessibility between older adults living in a low-density city and an ultra-dense city using comparable exposure and outcome measures. In addition, this PhD research program investigated between-city differences in the patterns (or mixes) of different types of destinations (latent classes of destinations) that are perceived to be accessible within specific walking distances from home and investigated the relationships between these classes of destination accessibility and older adults' walking for transport and recreation. Lastly, this PhD research program examined how other neighbourhood-level non-destination characteristics may moderate these relationships.

1.4 Thesis outline

This thesis consists of seven chapters. **Chapter 2** summarises the extant literature on neighbourhood environmental factors associated with older adults' PA, with specific focus on destination accessibility and walking for different purposes. This chapter also discusses several methodological issues in the research field of interest that have been addressed in this PhD research program.

Chapter 3 describes general methodological aspects of two large-scale epidemiological studies - one conducted in Brisbane, Australia and the other conducted in Hong Kong, China - that provided data for this PhD research program and the subsequent empirical studies presented in Chapters 4 to 6. Given that this thesis encompasses three

studies—Chapter 4, Chapter 5 and Chapter 6—that the first two studies have been published in peer review journals and the manuscript of the third study is under preparation, the data analytic plans and approaches for the single empirical studies are detailed in their respective chapters rather than in Chapter 3. The format, spellings, writing style and referencing style are in line with the requirements and guidelines of the journals where the respective scientific papers have been published.

Chapter 4 presents the first substantive study (Study One) addressing **the first major aim** of this PhD research program. The principal aim of Study One was to estimate and compare levels of neighbourhood destination accessibility based on older adults' perceptions of walking time (i.e., perceived destination accessibility within a 5-, 10 and 20-minute walk from home) between a low-density (Brisbane, Australia) and a high-density city (Hong Kong, China). The second aim was to investigate whether patterns of neighbourhood destination accessibility (i.e., mixes of destination types perceived to be accessible within a certain walking distance from home) would differ across the two cities. The third aim was to examine between-city differences in walking for different purposes and the fourth aim was to explore whether city-specific neighbourhood destination accessibility related to neighbourhood-level SES. The study titled "*Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China)*" has undergone scientific peer review and has been published in a high-quality international scientific journal— namely, *Cities*.

Chapter 5 covers the **second major aim** of this PhD research program and reports on the associations between the latent classes of neighbourhood destination accessibility within a 5-, 10- and 20-minute walk from home derived in Study One and older adults' self-reported walking for transport and recreation in the two cities. The study titled "*Associations between latent classes of perceived neighbourhood destination accessibility and walking behaviours*

in older adults of a low-density and a high-density city" has gone through peer review and has been published by a high-quality international journal in physical activity – namely, *Journal of Aging and Physical Activity* (JAPA).

Chapter 6 presents work related to the **third major aim** of this PhD research program, which was to investigate the moderating effects of neighbourhood non-destination characteristics on the associations between the latent classes of destination accessibility within 5-, 10- or 20-minute walk from home and walking for transport and recreation in older adults within the context of Hong Kong. The first aim of Study Three was to examine the moderating effects of individual neighbourhood non-destination characteristics – namely, safety, aesthetics and pedestrian infrastructure features - on the associations between the latent classes of destination accessibility and walking for different purposes, and the second aim was to investigate the moderating effects of latent profiles of the same neighbourhood non-destination characteristics on these associations.

Chapter 7 summarises and discusses the empirical findings presented in Chapters 4 to 6. It elaborates on the limitations and practical implications of the findings from the empirical studies included in this thesis. Finally, it suggests directions for future research.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2: LITERATURE REVIEW

This chapter provides an overview of the research related to characteristics of the neighbourhood environment that impact on older adults' PA, with specific focus on destination accessibility and walking for different purposes. Section 2.1 of this chapter provides a brief overview of socio-ecological models of PA and how they are relevant to research examining the effects of the environment on PA. Section 2.2 introduces key constructs used to characterise the neighbourhood environment and presents a narrative literature review and critique of published studies on aspects of the neighbourhood environment related to older adults' PA and, specifically, walking. Section 2.3 discusses several methodological issues that have been addressed in this PhD research program, including the operationalisation of destination accessibility and statistical approaches to examine the associations between destination accessibility and walking behaviours.

2.1 Socio-ecological models of physical activity behaviour

Current research on the effects of characteristics of the neighbourhood environment on older adults' PA has been in the main inspired by socio-ecological models of PA as they emphasise the importance of considering large-scale environmental influences on individuals' behaviours [72]. Socio-ecological models postulate that multiple layers of characteristics influence a person's behaviour [68, 70]. Factors influencing a person's active lifestyle include features at the intrapersonal, interpersonal, community, organisational and policy levels [4, 68, 70, 73, 76]. According to socio-ecological models, these factors form a hierarchical structure with individuals (intrapersonal factors) nested or clustered in their physical and social environment [74, 93, 94]. The neighbourhood environment's effect on people's behaviour is complex [76, 81, 95, 96] and still unclear [97]. The cross-level interactions make

it difficult to understand which characteristics, whether alone or jointly, influence individuals' activity patterns [70, 82, 98].

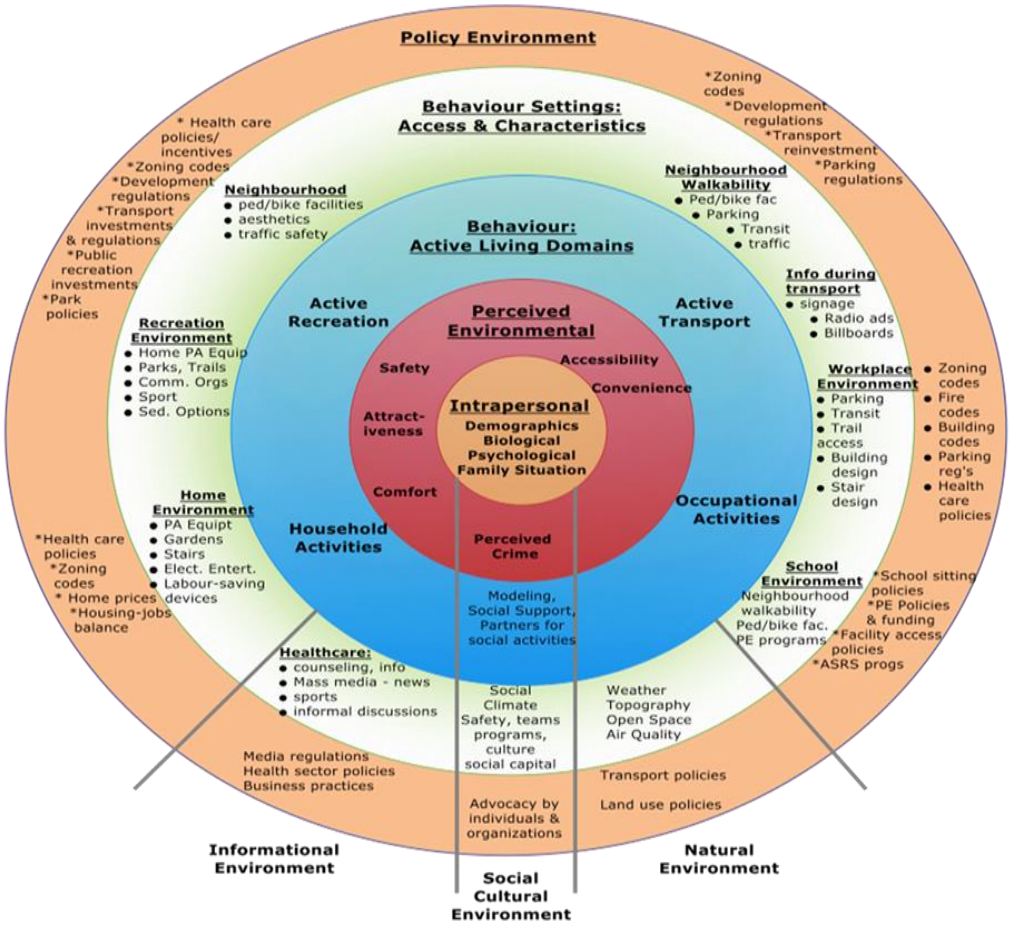
Figure 2 below shows the socio-ecological model of PA behaviour proposed by Sallis et al. [68] to help understand the complex nature of multi-level influences on individuals' activity patterns. The model forms a hierarchical structure with four multi-level components similar to an "onion-layered" structure [68, 70]. Across the hierarchical composition of the socio-ecological model are four levels [68]. The intrapersonal level (core-level) consists of individual-level factors including sociodemographic characteristics, biological as well as psychological attributes. The second level of the model is the perceived environment. This level represents how perceived environment features including safety from crime, personal safety, aesthetics, service / amenity convenience and accessibility influence individuals' active lifestyle. The third- and the fourth-level of the model are behaviour settings (access and characteristics) and policy environment. The former consists of physical attributes of the environment and places where individuals' activities occur, whereas the latter consists of policies (e.g. government policy, health care policy and social policy) in various organisations to promote active living. The policy environment may reflect the findings of effective population-based interventions [68, 69]. Land use, zoning, health care policy procedures and transportation directives may have an influence on various components of individuals' activity domain [68]. For example, the inability to implement public policies supporting empirical findings from environment-PA studies may be detrimental to achieving healthy behaviour outcomes [70, 77]. Between the second and third levels is the individuals' activity domain which comprises all the four domains of PA (active transport, active recreation, household activities, and occupational activities) [68]. The outer layer of the model comprises the informational, natural and socio-cultural environment. The natural environmental attributes include features such as weather, open space and air quality, while

the information environmental features consist of counselling services, education through mass media and news [68, 70].

In Figure 2, features of the natural environment and the informational environment interact with both the policy environment (where various procedures take place) and behaviour settings (where individuals' activity patterns occur) [68]. The socio-cultural environmental characteristics interact with people's activity domain across the model [70]. Examples of socio-cultural environmental features include social support, social cohesion, and neighbourhood SES. These features form interpersonal level factors in the multi-level framework - that is, how individuals interact with their social environment to perform the daily activity. Constructs that interact across the levels of the hierarchical structure of the socio-ecological models include socio-cultural and physical environmental factors. This distinguishes socio-ecological models from other theories that aim to target one or two levels of influence [70].

The rationale for employing socio-ecological multi-level models as an alternative approach to explaining individuals' health behaviours is that individuals' activity patterns are influenced by multiple levels of factors [68, 70, 99]. Furthermore, interventions based on the socio-ecological approach may affect individuals' behaviour at the population level [68, 70]. This is the principal public health's goal for promoting PA [4]. Socio-ecological models recognise the importance of intrapersonal (individual-level), social (interpersonal), and physical (actual and perceived) environmental attributes that influence individuals' activity patterns [69, 82, 100].

Figure 2: The multi-level socio-ecological model of physical activity proposed by Sallis et al. (2006)



Source: Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. Annual Review of Public Health, 27, 297-322

Individuals, especially older adults, spend the majority of their time in their neighbourhood [101]. Older adults are susceptible to being affected by both objective and perceived barriers in their neighbourhood environment [101]. For this reason, creating a health-promoting community environment that encourages an active lifestyle across all ages, especially the older adult population, has been recommended [4, 44, 73, 84, 102, 103]. Identifying correlates within the socio-ecological model that influence older adults' PA patterns will enable policy-makers to implement population-based interventions to promote higher levels of regular PA in this population [4, 69, 104]. Although a person's biological and genetic attributes play a major role in their active lifestyle and their health outcomes, their physical

and social neighbourhood environment also contributes in part [10, 74, 105, 106]. The proposed PhD program will investigate how the environmental components of the socio-ecological models influence older adults' activity patterns, while also acknowledging the importance and their interacting effects. Given that this thesis focuses on neighbourhood environmental factors (i.e., primarily destination accessibility), the subsequent section explores in more detail this particular aspect of the socio-ecological model of PA, with particular emphasis on the physical (built) environment.

2.2 The neighbourhood environment as a source of influences on PA behaviour

The neighbourhood environment consists of *social* and *physical (built) features* [75]. The neighbourhood social environment plays a considerable role in shaping health outcomes [73] and its influence on activity patterns has been consistently shown in numerous studies [69]. Neighbourhood social environmental attributes such as social cohesion, support from family and friends, and perceived safety from crime have been identified as correlates of older adults' activity patterns [73, 84, 96, 107]. Moreover, engagement in social activities has been shown to influence cognitive health [108], which may impact on PA. Other social environmental factors, such as racial discrimination and low neighbourhood SES also influence people's PA behaviour [69, 103]. Therefore, understanding how aspects of the neighbourhood social environment affect older adults' PA and moderate the associations between the other factors and PA is important for designing population-based interventions to promote active ageing.

The physical features of the environment have been hypothesised to have a substantial influence on individuals' activity patterns such as walking and cycling [24, 76, 109-111] and other forms of leisure-time PA [112, 113]. Individuals' travel behaviour (walking and cycling) in their neighbourhood is largely dependent on physical environmental features [69,

84, 114, 115], i.e., physical features of the neighbourhood environment may encourage or discourage individuals' transport-related activity patterns [96, 111]. The physical environment can be operationalised in terms of the actual (objective) and perceived environmental attributes [69]. It consists of *built* and *natural environmental features*.

The *built environment* component contains multifaceted features including transportation systems, land use patterns and the micro-scale urban design [76, 80, 84, 102, 116, 117]. Each element influences PA behaviour in a specific way [76, 102]. For example, access to recreational facilities, open spaces have been found to contribute to recreational PA, while higher levels of street connectivity, proximity and access to destinations have been shown to facilitate transportation-related PA [68, 85, 118, 119]. The built environment is a very complex, multi-faceted construct and this complexity extends to difficulties in understanding how it influences people's activity patterns in their neighbourhood [76]. The impact of a single feature of the built environment on residents' activity patterns may be insufficient to combat physical inactivity [76, 120]. Neighbourhoods with high residential density have been shown to have a positive impact on PA [121] because they are characterised by the presence of multiple environmental features supportive of PA, such as high levels of land use mix, street connectivity and access to public transport [120, 122]. As a result, it has been suggested that research in this field needs to consider a broad range of neighbourhood environmental correlates to detect the possible combined as well as independent effects of multiple features [119, 123, 124].

Frank et al. [76] categorised built environmental features into three components, namely, the *transportation system*, *land use mix patterns* and *urban design* [76, 117]. The *transportation system* of the neighbourhood built environment consists of features such as street networks, bicycle lanes, bus stops and road maintenance [76]. These features promote

PA levels in a particular way [84]. For example, availability of bicycle paths, sidewalk lanes, street networks and the proximity to destinations may promote higher levels of utilitarian forms of PA (walking and cycling for transport) [76, 96, 125]. Street connectivity can offer many or limited routes between destinations, which may determine the amount of time used or the distance covered to reach a planned destination [76, 122]. Two fundamental concepts that explain the transportation system are accessibility and mobility [126]. Accessibility means availability of destinations or activity sites within a walkable distance in residents' neighbourhood, while mobility refers to the propensity to travel between different destinations (e.g., from home to a planned destination such as a bus station or a shopping centre) [126, 127]. As time budget plays a very critical role in a person's decision to perform any activity [44, 68, 125, 128], the distance between destinations may play a substantial role in determining an individual's willingness to carry out a non-motorised activity such as walking or cycling [122, 126].

The second element of the built environment, *land use mix patterns*, pertains to the spatial distribution and diversity of facilities and services, such as commercial, residential, retail and public spaces, in the neighbourhood [76, 129]. These features offer individuals access to a diversity of destinations in their community [76, 130]. The spatial distribution of different structures within a particular area may contribute to the net residential density of buildings and people in that neighbourhood [76]. Densities and the land use mix patterns contribute to neighbourhood compactness and proximity, respectively [76, 126]. These features influence distance between destinations [76, 122, 126], as does street connectivity [76, 102, 131]. Research on active travel has shown that the distance from people's home to access a destination in their neighbourhood plays a key role in their decision to engage in non-motorised transport [76, 92, 96, 132, 133]. Travel time as a function of the distance between destinations [96] is a significant barrier to regular participation in PA [118]. It has

been reported that diversity of land uses within a particular neighbourhood decreases the distance between destinations [76, 118, 122] and this may promote walking behaviour within one's neighbourhood [76] because people may spend less time accessing a planned destination. This indicates that a neighbourhood environment with a mix of destinations within walkable distance and the removal of important barriers to walking may help promote PA levels among the residents [76, 118, 134].

Built environment features such as land use mix patterns, residential density and street connectivity have been found to promote people's travel behaviour [68, 69, 76, 84, 122] and have been reported to have a consistent association with PA across countries [135]. Composite measures of these characteristics are collectively referred to as *neighbourhood walkability indices* [68, 76, 136]. An area with higher levels of street connectivity offers alternative routes or direct access to planned destinations [120, 122] and, thereby, minimises the distances between two destinations [76]. This can encourage non-motorized activity as compared to neighbourhoods with less connectivity [102, 131, 137]. When destinations are within walkable distance, they may influence people's propensity to walk or cycle [125, 138]. Thus, a neighbourhood with a high level of walkability promotes walking and cycling for utilitarian purposes [69, 84, 100, 139]. Objectively-assessed land use mix patterns, street connectivity and residential density are built environmental features that have been consistently found to influence older adults' PA [120, 122, 140, 141]. Also, older adults' perceptions of their neighbourhood availability of facilities, proximity to destinations, street connectivity and access to diverse destinations in a community have been found to influence their transport-related walking behaviour [53, 80, 85].

The final component of the built environment is *urban design* [76]. Features of this element influence a person's perception of neighbourhood aesthetic and safety [76, 96] as well as their travel behaviour [142]. Examples of these characteristics include the size of the

footpaths, public spaces, street designs, benches and flowers or trees on the street [76, 96, 143]. While footpaths provide a safe environment for pedestrians to engage in active travel [122, 144] and have demonstrated a consistent association with PA across countries [135], aesthetic features in a neighbourhood have been shown to be associated with recreational walking [122]. These features complement other built environmental attributes to influence residents' travel behaviour and engagement in leisure-time PA [76]. For example, people's willingness to walk or use a bicycle may partly depend on their personal safety and the perception of beautiful features of their neighbourhood environment despite good access and proximity to a planned destination [76, 85]. The cross-level interaction between factors makes it unclear what type of features in the built environment should be targeted.

Pikora et al. [97] proposed a different conceptual framework than Frank et al. [76]. They categorised physical environmental factors into four categories: *functional features, safety features, aesthetic features* and *destination features* [97]. The *functional component* consists of physical features of the neighbourhood including street connectivity, traffic control devices, street width, street design and street maintenance that promote walking and cycling behaviour. A neighbourhood environment with poor designs is more likely to discourage PA patterns in older adults [116, 137]. Similarly, a community environment that has supportive and activity-friendly features such as sidewalks, street connectivity, mixed land use patterns and bicycle lanes, may promote walking and cycling behaviour in the residents [4, 69, 76, 114, 145]. The second component of the framework is *safety features* promoting a safe environment for walking or cycling. This component consists of the lighting system, crossing aids, surveillance as well as pedestrian crossings [97]. Perceptions of crime safety influences people's PA behaviour and also has a significant effect on their mental health [146]. Perception of safety from vehicular traffic has also been reported to influence PA behaviour [126, 146].

The third and fourth components of the conceptual framework are *aesthetics* and *destinations*, respectively. Examples of aesthetic features include parks, cleanliness, trees, architectural design and natural sights, while destinations include local facilities, shops, public transport and services [97]. Aesthetic features have been shown to promote neighbourhood walking behaviour [69, 84, 97, 125]. Access to attractive public places in a community have been linked to higher levels of PA [68, 118]. Attributes of destinations pertain to availability of and accessibility of different facilities and services [76]. Proximity and access to several destinations in a neighbourhood contribute to higher levels of PA [82, 118, 122, 130, 137]. While destinations are deemed to influence people's travel behaviour [85, 127, 147, 148], it is unclear which specific destinations matter the most [130]. Understanding which types of destinations matter for older adults' PA may assist policy-makers to implement population-based interventions to promote active ageing [68, 80]. However, the current lack of consistency in study results makes it difficult to address these issues [84, 102].

In summary, research examining the relationship between the neighbourhood environment and PA is rapidly increasing [149]. However, limited studies have focused on older adults, a vulnerable population subgroup [75, 116]. Secondly, published studies have reported inconsistent results [84, 102, 119, 150, 151]. The inconsistency in results may be due to the study designs, methods and operationalisations of environmental attributes and PA outcomes [99, 119] as well as a lack of investigation of covariates that moderate exposure pathways [24, 152, 153]. While overall access to and availability of destinations have been found to be positively associated with older adults' active travel behaviour in different countries [53, 85, 111, 154, 155], it is not clear what combination of destinations contributes to a higher level of this activity [53, 76, 156]. Also, it is unclear which types and mixes of destinations support engagement in recreational walking. Therefore, the main topic of this

PhD program was to determine the optimal mix of destinations that support active ageing (specifically, older adults' engagement in recreational walking and transportation walking) in two different geographical and cultural regions – namely, Australia and China. It is hoped that the results from this programme of research will assist policy-makers to formulate and implement environmental policies that will encourage active transport (especially, transportation walking) and recreational walking in older adults.

2.2.1 Destinations and walking

Destinations are considered to be accessible if they are within a walkable distance [96, 122, 154, 157]. Accessibility has been reported to be significantly associated with PA in studies from both the PA and transportation literature [96]. It is a physical environmental factor that is particularly important for older adults [85, 158]. Besides, access to different destinations in a neighbourhood may affect older adults' activity patterns, especially walking behaviour, in a variety of ways [78, 118, 159]. This is because individuals react to different neighbourhood environment settings differently [92].

There are two main ways in which neighbourhood destinations are measured: using objective measures (collected using environmental audits and Geographic Information Systems, GIS) [78, 85, 156, 158, 160]; and perceived or subjective measures [134, 154, 161, 162] (collected using self-report questionnaires) [163]. These two methods complement each other to provide meaningful information on neighbourhood environmental features [163]. Objective measures are based on data collected from environmental audits, which involve a systematic and empirical assessment of the neighbourhood environment [164] or archival data layers visualised in a GIS database [163]. The archival data layers are obtained through secondary sources and may contain information on land use zoning and location of destinations which allows the derivation of indicators of the mix of different land use in an

area and actual distance from a residential location to specific destinations such as shops, bus stops and parks [165]. On the other hand, perceived measures are collected through self-report questionnaires, the most popular being the Neighbourhood Environment Walkability Scale (NEWS), which was developed and assessed for validity and reliability by Saelens et al. [139] to evaluate neighbourhood environmental attributes. The NEWS has 98 items which form eight subscales: residential density; land use mix-diversity; land use mix-access; street connectivity; walking/cycling facilities; aesthetics; pedestrian/ traffic safety; and crime safety [139]. The land use mix-diversity and the land use mix-access subscales are both perceived measures of destinations according to Pikora et al.'s [97] conceptual framework.

2.2.1.1 Summary of evidence: Destinations and older adults' walking for transport

Considerable attention has focused on how access to destinations in the community are associated with older adults' utilitarian walking (i.e., transportation walking) [85, 96]. Examples of frequently assessed destinations in the literature include access to public transport or bus stops, goods and services, financial and social services, medical services, recreational destinations, shopping centres, parks, grocery and convenience stores, posting facilities, restaurants, religious places, coffee shops and schools [85, 159, 166]. Providing an opportunity and easy access to popular utilitarian destinations within walkable distance in the neighbourhood environment is an efficient and sustainable way of promoting active ageing [4, 96]. Relationships between access to destinations and PA in the general population have been investigated in numerous studies across geographic regions [156]. For example, they have been examined in Australia [118, 130, 160], in the U.S. [154, 161, 167], Hong Kong [85, 134, 162, 168], Belgium [169] and New Zealand [170].

Specific types of destinations have been shown to support transportation walking for errand purposes in older adults [83]. A recent systematic review and meta-analysis by Cerin

et al. [53] found some evidence of a positive association between access to public transport and walking for transport. Specifically, in Chinese older adults, the presence of public transit points [85] and access to public transport [134] associated positively with overall walking for transport. However, the same study [134] did not identify a significant association between access to public transport and within-neighbourhood walking. Similarly, a Canadian study observed a significantly positive association between access to public transport and frequency of walking trips among Canadian older adults [171]. Further, findings by Procter-Gray et al. [166] among U.S. older adults confirmed a positive relationship between access to bus stops and transportation walking. Among Australian older adults, perceived access to proximate public transport positively correlated with walking for transport [172].

Access to retail destinations, such as grocery stores and restaurants, has shown a significant and positive relationship with walking for transport among Chinese older adults [85] and in U.S. older adults [166]. Two studies also found positive relationships between access to food outlets and walking for transport within the neighbourhood [85, 166]. Also, access to parks and recreational facilities showed a significant and positive relationship with walking for transport among U.S. [161], Japanese [18] as well as Chinese older adults [85, 168].

Other types of destinations have shown mixed results with walking for transport. These include business and institutional destinations [85, 166]. Accessibility of and proximity to a bank was negatively related to transportation walking among Canadian older adults [173], while access to the post office showed a positive association [166]. Cerin et al. [85] did not detect a significant association between the prevalence of and the diversity of government/public destinations and transportation walking among Chinese older adults.

Health-related destinations also showed mixed findings. Proximate access to health-related destinations, such as pharmacies, was not significantly associated with walking for

transport in Canadian older adults [173]. However, diversity but not the prevalence of health-related services showed a positive relationship with within-neighbourhood transportation walking among Chinese older adults [85]. An Australian study found a positive association between proximity to health services and walking for transport [172], and Procter-Gray et al. [166] observed similar positive patterns among U.S. older adults.

Prevalence of religious places in a neighbourhood showed no association with transportation walking, but the diversity of worship facilities showed a positive association in Chinese older adults [85]. A Canadian study found a positive association between the presence of religious facilities and transportation walking [173]. The presence of and diversity of entertainment facilities in a community have also been shown to have no significant association with transportation walking among Chinese older adults [85] as well as Australian older adults [174].

Strong and conclusive evidence supports the importance of having diversity and variety in land uses (different categories/types of destinations) within the neighbourhood [85, 96, 166]. Higher levels of diversity of land use have been reported to be positively correlated with overall transportation walking in Singapore [111] and within-neighbourhood walking for transport among Chinese older adults in Hong Kong [134]. However, the same Hong Kong study failed to find an association with overall walking for transport. Barnett et al. [168] reported a positive association between weekly frequency of transportation walking and access to a variety of land uses. Access to a mix of land uses was positively correlated with transportation walking for errand purposes among older adults in the U.S. [161, 166], China [134] and Singapore [111]. Moniruzzaman et al. [173] found that destination mix was positively associated with transportation walking among Canadian older adults.

In addition to examining main effects of destinations on PA, a few studies have also considered how individual-level factors moderate the relationship between destinations and

walking [53, 85, 166]. Individual level factors that have consistently appeared in literature as correlates of PA are age, educational attainment, gender and health conditions [53, 134, 159, 161, 168]. For example, in Japanese older adults, a significant and moderating effect of gender was found. Namely, only women showed a positive association of transportation walking with access to shops/commercial destinations, recreational places and parks [159]. Also, among Chinese older adults, age moderated the association between diversity of land use and transportation walking, with only older adults aged 75+ showing an association [134]. Similarly, among U.S. older adults, age (people aged 75 and over) has been shown to have a significantly positive moderating effect on the association between transportation walking and access to recreational facilities and park [161]. Health conditions, on the other hand, have been identified as moderators of the relationships between access to destinations/services and walking for transport in Chinese older adults [168], while functional capacity [166] was reported as a moderator in U.S. older adults.

Even fewer studies have considered how environmental characteristics, such as access to pedestrian infrastructure and traffic and personal safety, moderate relationships between destinations and walking for transport [85]. Cerin et al. [85] found that the presence of stray animals and signs of crime/disorder were moderators of the association of access to religious places and recreational facilities with within-neighbourhood transportation walking. The same study found pedestrian infrastructure, such as path conditions and sloping streets, to moderate associations of transportation walking with access to shops/ commercial destinations. The observed moderation effects were theoretically plausible because they suggested that the availability of shops/commercial destinations in the neighbourhood was supportive of walking only in the absence of other environmental barriers, such as sloping streets. Older adults with mobility problems may find it difficult to walk to local shops if the streets are too steep. Also, another study found that the distance between individuals' homes

and destinations moderated the associations of transportation walking with access to neighbourhood amenities in U.S. older adults [166]. These findings indicate that environmental factors need to be examined as moderators when investigating the effects of access, availability and diversity of destinations on older adults' active travel.

2.2.1.2 Summary of evidence: Destinations and older adults' walking for recreation

Studies examining access to neighbourhood destinations and relationships with walking for recreation in older adults have mostly reported non-significant results [57, 110, 113, 161, 162, 174]. Even when considering access to specific destination types, non-significant associations with recreational walking have been reported for shops and commercial services [113, 162, 166, 175], institutional and industrial services [166], health and aged-care facilities [166, 172] and public transport [159, 166, 174]. Evidence shows that these types of destinations correlate with transportation walking [53, 85, 134, 166, 172, 173] rather than recreational walking. This suggests that the above-mentioned types of destinations are important for utilitarian purposes but rather irrelevant to recreational purposes.

Evidence is mixed and inconclusive on the importance of recreational facilities for recreational walking. In Chinese older adults, Cerin et al. [162] reported that perceived proximity to exercise facilities was positively correlated with within-neighbourhood recreational walking. In Perth, Western Australia, Boruff et al. [175] found objectively-measured proportion of recreational and park land use to be positively associated with the odds of walking for recreation in some but not all neighbourhood buffers assessed. The same study found that although access to specific types of recreational facilities did not influence recreational walking, the presence of a clubhouse within retirement villages was positively correlated with walking for recreation [176]. However, despite some positive associations

reported, many studies have found no association between access/presence to proximate recreational facilities and recreational walking [161, 168, 176-179].

Other studies have explored the relationship of access to parks and open space with recreational walking and reported inconsistent results. Several studies have identified non-significant results [161, 166, 179-181]. Contrary to these results, older adults in the UK who had access to aesthetically pleasing natural open spaces were more likely to engage in at least 60 minutes of recreational walking per week [182]. Also, among Chinese older adults, access to parks was positively and independently associated with recreational walking [113]. The inconclusive evidence in the literature for the association between access to parks and open space and recreational walking in older adults can be viewed in several ways. For example, the presence of parks alone may not be enough to encourage older adults to engage in recreational walking; the perceived quality and attractiveness of the park may be more important.

Studies have also considered the importance of land use mix diversity for older adults' recreational walking and have found mixed results. Seven studies observed no associations [57, 115, 162, 166, 168, 174, 181], while one study found land use mix diversity (measured using the NEWS subscale) to be positively associated with the amount of recreational walking, but only in older adults aged 66-75 years and not in those aged 76+ years [161].

Even though no main effects of access to destinations, specific destination types and destinations diversity on recreational walking have been found, some individual factors have been shown to moderate the association between neighbourhood destinations and older adults' walking for recreation [68]. Age, gender, health conditions, driving status, income level and educational attainment have been considered as individual level moderators [161, 180]. In the U.S., age has shown a significant moderating effect on the association between

access to land use mix- diversity and recreational walking, with only younger older adults (i.e., people aged 65-75 years) showing a significant association [161]. Also, educational attainment moderated the association of access to neighbourhood destinations and recreational walking in Chinese older adults. Specifically, the association was positive and stronger in those with no formal education [162]. Besides, among U.S. older adults, a person's driving status moderated the association between recreational walking and access to a diversity of land uses in their neighbourhood [181].

Only two articles have studied environmental factors as moderators of the relationship between destinations and walking for recreation [113, 183]. Bracy et al. [183] found that pedestrian safety had a positive and significant moderating effect on the association between access to recreational facilities and recreational walking in U.S. older adults. Cerin et al. [113], on the other hand, identified the presence of unattended animals as a moderator of the association between walking for recreation and access to playground and parks in Chinese older adults. Additionally, the same study found signs of crime/disorder to moderate the relationship between older adults' recreational walking and access to parks and outdoor sports field. Specifically, positive associations were found only in the absence of signs of crime/disorder.

From this summary of evidence on the potential effects of destinations on older adults' walking behaviour, it is clear that most of the findings published to date are inconsistent. The difference in findings may be due to the use of different methodological approaches [175] but also to the way destinations are operationalised and the existence of complex interaction effects of destinations types with individual and environmental factors. Therefore, it is important to systematically examine how different ways of operationalising destinations types and mixes correlate with older adults' walking behaviours while

considering theoretically plausible moderators proposed by the socio-ecological model of PA [68].

2.3 Methodological issues related to research on destination accessibility and older adults' PA

In this section, methodological issues arising from a critical examination of published studies on destinations as correlates of older adults' PA (especially walking) are described and linked to the rationale of this PhD research program.

2.3.1 Operationalisation of destination accessibility in the neighbourhood

The neighbourhood environment is often operationalised using administrative boundaries, such as Census tracts [53, 98, 184]. More recent studies have defined neighbourhoods using 0.5 km or 1 km areal or street-network buffers surrounding participants' homes [185]. Destination measures are created by summarising information on the availability of non-residential destinations within a neighbourhood [184]. Destinations have been typically operationalised in the form of an entropy index, prevalence measures, diversity measures and distance measures.

Entropy measures are computed using data on the proportion of different types of land uses (or destinations categories) within a neighbourhood [186]. For example, areas occupied by destinations such as grocery stores, restaurants and other services could be classified under a common 'commercial' land use category [184]. Entropy measures quantify the level of heterogeneity of land uses within a neighbourhood [184]. The average value ranges between 0 to 1, whereby 0 indicates homogenous land uses and 1 indicates maximal heterogeneity in land uses [186].

Diversity measures share similar characteristics to entropy measures, but they use different computational approaches. They indicate the number of diverse types or sub-types

of destinations in the neighbourhood. For example, a neighbourhood with three recreational destinations and two shopping centres would score 2 on a general diversity measure of destinations (because, in this case, the neighbourhood has only two types of destinations – namely, recreational destinations and shopping centres) [85].

Prevalence measures correspond to the actual number of all destinations or destinations categories within a neighbourhood [85]. For example, a neighbourhood with three recreational destinations and two shopping centres would score 5 on a general prevalence measure of destinations (because the neighbourhood, in this case, has five destinations in total) [85]. Prevalence measures can be also expressed as density measures if the number of destination is divided by the land area of a neighbourhood [121]. Distance to the nearest destination (e.g., public transport stop) represents another way of quantifying accessibility to specific types of destinations [185]: the more distant a destination, the lower its level of accessibility. These traditional ways of operationalisation of destination accessibility [85] have been widely used in studies investigating the associations between destinations and PA. However, little is known about how different mixes of destinations can affect individuals' walking behaviour, especially in older adults [53]. In order to study this issue, Clarke et al. [75] suggested that researchers should depart from the conventional variable-focused approaches of operationalising destinations and instead use a person-focused approach that classifies residents according to the mixes of destinations in their neighbourhood. Such an approach yields categorical destination variables that represent membership to specific mixes of destinations. For example, some older adults may live in neighbourhoods with a high prevalence of recreational and residential destinations, while others may live in neighbourhood characterised by commercial, institutional and residential destinations. These two groups of older adults would be classified under two different destination mix categories representing categorical destination variables.

2.3.2 Statistical approaches to examining neighbourhood destination accessibility and PA associations

To estimate destination-PA associations in older adults according the assumptions of the socio-ecological model of PA, studies have typically utilised various types of regression modelling [85, 98, 134, 162, 163, 187] including destination main effects and destination(s) by potential moderator(s) interactions effects on PA [53]. However, it could be argued that this approach can not address the complex nature of the environment-PA relationship because they represent variable-oriented techniques [98]. The interaction between older adults (i.e., their personal characteristics) and their neighbourhood is complex and multidimensional, and for this reason, a "variable-centred" technique may not have the capacity to address the underlying structural relationships [98].

Regression techniques applied in previous research on destinations and older adults' PA focused on identifying associations between variables and typically assumed that the observed associations applied across all participants [188, 189]. This assumption is not in line with a life-course perspective and socio-ecological approach according to which older adults differ in health conditions, functional capacity [89, 106, 190] and mix of physical and social environmental conditions they are exposed to [113]. In other words, older adults are a heterogeneous group in terms of their physical ability and environmental opportunities to participate in PA. The various profiles of environmental conditions and individual characteristics likely interact in complex ways to yield a specific PA outcome.

Giles-Corti et al. [92] recommended structural equation modelling as an alternative analytical approach to estimate the interrelationships between person-environment factors. However, structural equation modelling is also a variable-oriented approach that focuses on assessing the direct and indirect influence of several indicators simultaneously. Similarly to 'standard' regression models, structural equation modelling with higher-order interaction

terms that capture multidimensional relationships may result in unstable parameter estimates of associations [191].

As noted earlier, few studies have attempted to examine interactions of various environmental and individual factors on PA in older adults using a variable-centred regression approach [70, 113]. Even though these studies identified some promising interaction effects, their approach lacked statistical power to address more complex relationships (e.g., three or four-way interactions) [98, 192]. Moreover, variable-centred approaches may inflate the type I error rate when multiple comparisons are performed [193]. Also, these approaches may present computational challenges when a large number of multi-level variables are examined and/or when higher-order interaction terms are included in the model [98, 191, 192].

Cerin et al. [53] and Frank et al. [120] recommended investigating the influence of a combination of several environmental attributes on individuals' activity patterns. To do this, a robust statistical classification technique, in particular, a person-focused approach may be the best alternative to address the methodological challenges outlined above. This approach would identify the as-yet unobserved subgroups of older adults with specific patterns (*aka* classes or profiles) of socio-demographic characteristics and environmental exposures and, then, relate these subgroups to PA outcomes. Popular 'data reduction' methods such as principal component analysis and factor analysis can identify groups of variables that tend to co-vary, however they focus on identifying unobserved factors that explain correlations between observed variables rather than between observations (participants) [192, 194]. A frequently-used person-centred technique called cluster analysis is also not optimal for this purpose because it is very sensitive to the scaling of the data [194, 195]. Also, cluster analysis is not a model-based approach. It does not yield model indices and has no formal approach to determining the required number of classes (or categories) of observations (participants)

[187, 195]. Other person-centred approaches (outlined below), which have been employed in this PhD program, are a more suitable alternative to address the methodological challenges mentioned above.

2.3.2.1 Latent class and latent profile analyses as suitable person-centred analytical approaches to examine the association between destination accessibility and older adults' PA As noted above, most of the studies that have examined associations of destinations with older adults' PA used a variable-focused approach which is not particularly suited for the identification of higher-order interactions between individual and environmental variables on PA outcomes. Model-based person-focused analytical approaches provide a better solution because they can identify higher-order interactions between types of destinations - i.e., they can identify mixes of destinations that are optimal with respect to specific PA outcomes. As noted above, cluster analysis is not a robust and appropriate person-focused method. A superior alternative person-focused (clustering) approach is latent class analysis (LCA) and latent profile analysis (LPA) [188, 195-197].

LCA is a probabilistic model-based clustering approach from the class of mixture models [98, 124, 196-198]. Mixture models postulate that observations come from a finite number of non-overlapping, categorical and distinct unobserved subgroups in the study population [187, 192]. LCA is applied when variables used for classification of observations are categorical [188]. LPA is a special variant of LCA, which is used when variables used in classification are continuous [188, 194, 195, 199]. Latent Transition Analysis (LTA) is used when dealing with longitudinal dataset [188]. LCA/LPA detect homogeneous, mutually exclusive and distinct unobserved subgroups called latent classes/profiles using the observed variables [188, 200, 201].

The derived latent classes are categorical latent variables that represent subgroups or typologies. Participants (observations) are similar within their respective subgroups and dissimilar between various subgroups [200]. Participants have different, unknown and non-zero probability class membership in their respective latent class typology [187, 192]. LCA is conceptually similar to factor analysis but factor analysis is variable-focused, cannot handle categorical and continuous variables simultaneously, and the latent variables called factors are continuous and follow a normal distribution [98, 188]. In contrast, LCA is able to handle a mix of categorical and continuous variables, and the derived latent variable is categorical and follows multinomial distribution [188]. LCA is an unsupervised statistical technique like cluster analysis (inferring a function to describe a hidden structure from "unlabelled" data, i.e., data that do not include information on classification or categorisation) [202]. However, the primary distinction is that the LCA is a model-based and probabilistic technique (with a given individual having a non-zero probability of belonging to any of the identified latent classes) [195], whereas cluster analysis is deterministic (with a given individual belonging to only one of the identified classes). LCA uses a model that describes the distribution of the data. Then, based on this model, LCA estimates the probabilities that specific observations (individuals or neighbourhoods) are members of certain latent classes. While LCA starts the analysis by describing the distribution of the data, cluster analysis relies on arbitrary distance measures to find clusters of ‘similar’ observations.

Another advantage LCA has over cluster analysis is that it can address the potential bias associated with measurement errors in surveys which, in turn, can lead to classification errors [98]. LCA can address this problem if different survey items are used to obtain repeated measurements of an outcome. LCA offers a strong complement to variable-centred approaches [187, 195] because it incorporates both variable-centred and person-centred techniques. It is robust and stable in dealing with scaling issues in the dataset [195].

LCA/LPA have been applied to a range of health and behaviour topics including drug use patterns, dietary eating habits and environmental determinants of PA [98, 124, 203, 204]. LCA/LPA provides an excellent opportunity for investigators to identify critical research questions for further examination [187]. Once latent classes/profiles are derived, investigators can examine how the classes/profiles of destinations relate to participants' health behaviours and health outcomes [187]: e.g., how different mixes of destinations in the neighbourhood relate to the older adults' walking behaviour or any other clinical outcome.

The popularity of LCA in public health research has been gradually increasing. It has successfully been applied to studies on neighbourhood correlates of PA in samples of adolescents [205] and adults [123]. Only two studies from the U.S. [204] have applied it to data collected on older adults to identify the optimal mix of neighbourhood environmental attributes facilitating engagement in PA. Adam et al. [204] used LPA on several questionnaire-based variables collected in two U.S. cities (Seattle, WA and Baltimore-Washington, DC) and identified 4-profile solutions from Baltimore-Washington, DC data and 3-profile solutions from Seattle, WA data. Todd et al. [194], on the other hand, used LPA on objectively-measured data from the same study by Adams et al. [204]. They identified 3-profile distinct subgroups. They identified higher levels of PA in residents of socially and environmentally advantaged communities compared to less advantaged communities.

To date, no study has examined how different mixes of destinations in the neighbourhood can affect older adults' walking behaviour (i.e. walking for transport or walking for recreation). Additionally, no study has examined differences in latent classes/profiles of environmental attributes within a low-density vs. a high-density context. This PhD research program aimed to resolve this knowledge gap by, first, identifying mixes of neighbourhood destinations in Brisbane, Australia and Hong Kong, China and, subsequently, by estimating how these mixes are related to older adults' walking behaviour.

In doing so, the interacting effects of neighbourhood-level characteristics (e.g., crime and traffic safety, pedestrian infrastructure) with destination accessibility were considered. Hence, the main objective of this PhD program was to address some of the methodological limitations encountered in the research field of neighbourhood environmental determinants of older adults' PA pertaining to how destinations are operationalised and complex interaction effects examined. At the same time, it aimed to provide substantive findings by identifying the destination mixes influencing the walking behaviours of older Australians and older Chinese and how these destination mixes interact with other environmental factors.

CHAPTER 3

METHODOLOGY

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter describes the methodology employed to address the research aims within this thesis. It elaborates in detail the data sources, study settings, sampling procedures, data collection, measures and statistical data analyses utilised to achieve the aims of this thesis. The overall purpose of this PhD research program was to examine the link between destination accessibility based on perceptions of walking time from home and walking for different purposes in older adults. This chapter has been divided into three sections: the first section describes the data sources, study settings, sampling procedures and data collection procedures; the second section describes the study measures; and the third section describes the statistical data analytical strategies adopted to address the research aims.

3.2 Section One

3.2.1 Data sources

This thesis used observational cross-sectional data from extant epidemiological studies on environmental correlates of PA in older adults conducted in the two cities—Brisbane, Australia (in 2007-2011) and Hong Kong, China (in 2007-2008). Specifically, the study conducted in Brisbane, Australia used data from the **H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and Ac**T**ivity (HABITAT) [153], while the Hong Kong study used data from Hong Kong Elderly study [163]. The HABITAT study was funded by the (Australian) National Health and Medical Research Committee (NHMRC) (Grant ID: 290521; 497236) and received ethical approval from the Human Research Ethics Committee at the Queensland University of Technology (ID 3967H) [153]. The Hong Kong Elderly study was funded by the Health and Health Services Research Fund (Grant number: 04060671) and received the ethical approval from the Ethics Committee of the University of Hong Kong and the

Department of Health, Government of Hong Kong SAR [163]. The datasets became accessible for use after I received ethics approval (ACU Application ID: 2017-248N) from the ACU Human Research Ethics Committee in 2017. The HABITAT study data were requested and received from **Professor Gavin Turrell** (Principal Investigator (PI) of the HABITAT study and former faculty member at the Institute for Health and Ageing (currently closed)) and his team, while the Hong Kong Elderly study data were associated with my PhD research scholarship —"*Urban Space and Active Ageing Research*"— of which **Professor Ester Cerin,** my primary supervisor, was the PI.

3.2.2 Settings

As indicated earlier, the data sets for this PhD research program came from two epidemiological studies— the HABITAT study and the Hong Kong Elderly study. While the two cities have similar sub-tropical climatic conditions, several characteristics vary considerably, including population density, socio-demography, ethnicity and transportation systems.

3.2.2.1 The HABITAT study

The HABITAT study was undertaken in Brisbane, Australia (in 2007-2011). Brisbane is the capital city of the state of Queensland and the third-largest city in Australia after Sydney and Melbourne, with an estimated resident population over 2.4 million between 2017 and 2018 [206]. In 2018, at 9,637 square kilometres, Brisbane city was recorded as having the largest Greater Capital City Statistical Area in Australia and a low population density (less than 500 people per square kilometre) [206]. Additionally, Brisbane is a car-dependent city with car ownership of 565 cars per 1,000 people in 2011 [207]. Furthermore, in 2016, the Australian Bureau of Statistics (ABS) census data recorded that the median age of the residents in

Brisbane was 35 years, with older adults making up 13.4% of the total population [208]. Male residents constituted 49.2% of the population, while female residents comprised 50.8% of the population. Brisbane's population is made up of people from diverse ethnic backgrounds. The most common ethnic groups include English (26.6%), Australian (23.2%), Irish (8.8%), Scottish (7.4%), German (4.3%) and the Aboriginal and/or Torres Strait Islander people (2.4%). The average household size was 2.7 people, with a median weekly household income of AU1,562.00. The average number of motor vehicles per dwelling was 1.8. Regarding the means of transport, 11.6% of the population used at least public transport mode (i.e., train, bus, ferry and tram/light trail) as transportation to their workplace, while 69.0% used a car (either as driver or as passenger) [208]. In 2018, Brisbane city council has implemented sustainable strategic policies that ensure safe, efficient, comfortable and all-inclusive accessible public transport in order to lower the level of car dependency [209].

3.2.2.2 The Hong Kong Elderly study

The Hong Kong Elderly study was undertaken in 2007-2008. Hong Kong, located in the south-eastern of China, is a Special Administrative Region of the People's Republic of China [210]. Hong Kong is an ultra-dense city with approximately 7.39 million people and an average population density of 6,830 people per square kilometre in 2017. In Hong Kong, the primary language is Cantonese, spoken by 88.9% of the population in 2016. However, both Chinese and English are the official languages in Hong Kong. In 2016, the English language (primary language of 4.3% of the population) was widely used in the Government, business, professional and legal sectors [210]. Approximately 92.0% of the Hong Kong population were of Chinese ethnicity. Among the non-Chinese, the largest ethnic groups were Filipinos (31.5%), Indonesians (26.2%) and Whites (10.0%). Hong Kong has an increasing trend in

the proportion of the older adults, rising from 12.4% in 2006 to 15.9% in 2016 [211]. In 2016, the older adult population was 1,163,153, comprising 53.0% aged 65 to 74 years, 17.7% aged 75 to 79 years and 29.0% aged 80 years and over [211]. The median monthly domestic household income was HK$ 25,000 (equivalent to AUD$ 4717) [212]. Globally, Hong Kong has one of the best transportation systems with over 12.7 million passenger journeys daily, using efficient, affordable and multimodal public transport that includes railways, trams, buses, public light buses, taxis and ferries [213]. In 2014, the rate of car ownership was approximately 68 cars per 1, 000 people [214].

3.2.3 Sampling procedure

The two studies used sligthly different sampling procedures to identify study areas and recruit study participants. The HABITAT study used two-staged sampling stratified by area-level SES, while the Hong Kong Elderly study used two-staged sampling stratified by area-level SES and walkability.

3.2.3.1 The HABITAT study

HABITAT is a longitudinal multilevel study that investigates the environmental correlates of PA in residents of Brisbane aged 40-65 years at baseline [153]. The HABITAT study commenced in 2007 and employed two-stage stratified random sampling to identify individuals living in 200 administrative areas (Census Collection Districts) in Brisbane [153]. The two-staged stratified random sampling procedure first selected 200 administrative areas (neighbourhoods) and then sampled study participants within the selected neighbourhoods. The areas were sampled to ensure a broad representation of neighbourhood-level

socioeconomic status (NSES) [215]. Although HABITAT is a longitudinal multilevel study, this thesis used only cross-sectional data collected in 2011 (Wave 3) to maximise the number of older adults (participants aged 65 years and older) in the analytical sample.

Stage 1: Stratified random neighbourhood selection

The HABITAT study first selected Census Collection Districts (CCDs) stratified by deciles of NSES. NSES was defined using the Australian Bureau of Statistics' (ABS) ranking of 1625 CCDs based on deciles of Index of Relative Socioeconomic Disadvantage (ISRD). Twenty CCDs were selected randomly from each decile of ISRD. Hence, the total number of selected CCDs was 200. Figure 3.1 below presents the HABITAT study coverage area. The HABITAT study covered 200 neighbourhoods (CCDs) categorised into 10 levels of NSES, which are represented in Figure 3.1 by different colours. The most advantaged neighbourhoods (higher NSES) are those marked with warmer colours (e.g., orange and red), while the most disadvantaged neighbourhoods (low NSES) are those indicated in cooler colours (e.g., green and darker green).

Figure 3.1: HABITAT study coverage areas

Stage Two: Random selection of participants

The Australian Electoral Commission (AEC) database was used to identify all the households that had at least one participant aged 40-65 years within the selected 200 CCDs. On average, a total of 85 households per selected CCD were sampled using a systematic without replacement probability-proportional-to-size sampling. This amounted to 17,000 households (i.e., 85 households multiplied by 200 CCDs). A participant (40-65 years of age) per household from 17,000 households across the 200 CCDs was randomly selected [153]. Figure 2 below illustrates the two-stage stratified sampling procedure used to recruit the participants.

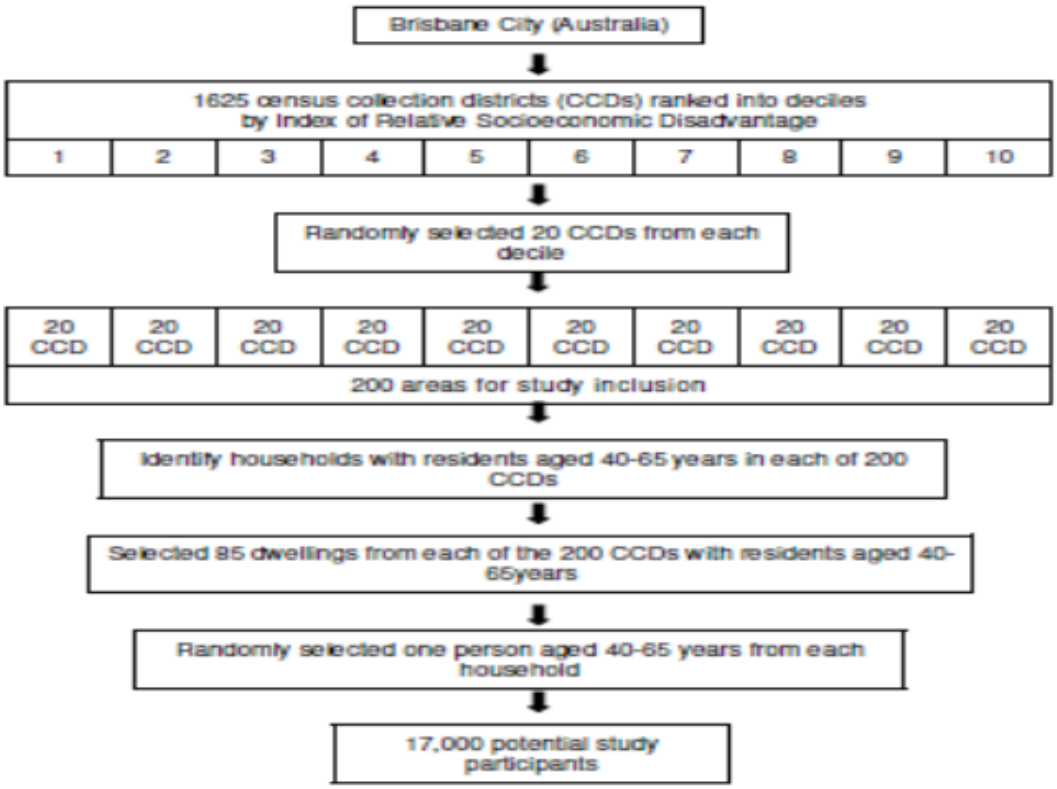


Figure 3.2: Overview of the sampling procedure to recruit HABITAT study areas and participants.

3.2.3.2 Hong Kong Elderly study

The Hong Kong Elderly study was conducted in 2007-2008 and collected data on neighbourhood environmental correlates of older adults' PA [163, 216]. The study recruited 484 participants from a list of clients of four Hong Kong Elderly Health Centres (EHCs) representing catchment areas of low and high transport-related walkability and NSES. The EHCs were established by the Department of Health of the Hong Kong Special Administrative Region to provide comprehensive primary care services to residents aged ≥ 65 years. The sampling procedure was divided into two stages—neighbourhood sampling and then the recruitment of participants.

Stage 1: Stratified random neighbourhood selection

A multi-stage sampling strategy was used to identify 32 study communities (street blocks) falling within the selected EHCs' catchment areas (8 street blocks per catchment area). In general, clients of the EHCs are representative of the Hong Kong population of older adults [134]. A random selection without replacement was used to identify eight street blocks from each of the four EHCs' catchment areas. The NSES was operationalised into low- and high-SES based on census data on median monthly household income and percentage of owner-occupiers. A transport-related walkability index was constructed using data on household density, intersection density and commercial/service destinations. Low- and high-NSES groups of street blocks within EHCs catchment areas were first ranked by transport-related walkability. Street block groups were then classified to represent the following neighbourhood-type strata: (1) high walkable/low NSES; (2) high walkable/high NSES; (3) low walkable/low NSES; and (4) low walkable/high NSES [163].

Stage Two: Random selection of participants

Within each of the eight-street blocks per four neighbourhood types, residents were recruited from membership lists of the four selected EHCs based on the following three eligibility criteria: (1) able to walk without any form of support; (2) able to communicate in Chinese; (3) and without any evidence of diagnosed cognitive impairment. In total, 484 participants from 32 neighbourhoods who met the above eligibility criteria were recruited to participate in the study.

3.2.4 Data collection

The two studies used different data collection approaches to recruit study participants. While the HABITAT study employed a structured self-administered mail questionnaire, the Hong Kong Elderly study used an interviewer-administered questionnaire to recruit all the participants.

3.2.4.1 HABITAT study

Questionnaires were mailed to the selected households between May and July during the following years: 2007 (baseline, Wave 1), 2009 (Wave 2), 2011 (Wave 3), 2013 (Wave 4) and 2016 (Wave 5) to assess participants' experiences of their neighbourhoods including a wide range of factors that might influence residents' PA behaviour and health outcomes, such as individual-level SES and perceptions of their neighbourhood environment [153]. Perceived aspects of the neighbourhood environment included crime safety, traffic safety, street connectivity, scenery and proximity of destinations and services from the respondent's residential address. A week before the questionnaires were posted, personalised letters were sent to all the participants to indicate the importance of their responses in the survey.

Pre-addressed pre-paid envelopes were included in the questionnaire package for return of responses. Postcards were mailed a week after to thank the participants who provided their responses and to remind those who were still in the process of responding to the survey. Personalised reminder letters and replacement questionnaires were sent to the non-respondents seven weeks after the first questionnaire items were sent. For this PhD research program, observational cross sectional data collected in 2011 (Wave 3, response rate 67.3%) were utilised to investigate participants' perceptions of neighbourhood destination accessibility and walking for transport and recreation.

3.2.4.2 The Hong Kong Elderly study

An interviewer-administered questionnaire was used to collect participants' socio-demographic data and environmental correlates (i.e., perceptions of the neighbourhood environment) of PA, mainly walking for transport and recreation. A 40-minute face-to-face interview was administered in Chinese (specifically, Cantonese) to collect data. After completion of the survey, participants were given a grocery voucher. The reported response rate was 78% [163].

3.3 Section Two: Measures

This section provides detailed information on the relevant variables used in this thesis. These variables include perceived destination proximity as an exposure measure of destination accessibility, weekly frequency and minutes for walking for transport and recreation as outcome variables, perceived neighbourhood non-destination characteristics as exposures and moderators and participants' sociodemographic characteristics and NSES as covariates. The selection of the relevant variables was based on the conceptual model proposed in this thesis (Figure 1).

3.3.1 Perceived neighbourhood destination accessibility

For the purpose of this PhD research program, items measuring proximity to specific types of destinations based on older adults' perceived time to walk from home to the nearest destination (of a specific type) that were comparable across the two studies were identified. To measure perceived proximity to destinations, the two studies used comparable validated and reliable instruments based on the Neighbourhood Environment Walkability Scale (NEWS) [139, 217]. The HABITAT study employed the original version of the Neighbourhood Environment Walkability Scale-Abbreviated (NEWS-A) to measure perceived distance to 20 different destination types [139, 217]. These items were part of the land-use mix—diversity subscale of the original version of the NEWS-A [139, 217]. The Hong Kong Elderly study used the land-use mix – diversity subscale of the NEWS for Chinese Seniors (NEWS-CS) to measure older adults' perception of walking time needed to access 30 types of destinations in their neighbourhood environment [163]. The NEWS-CS represents a version of the NEWS-A adapted for Chinese older adults. The original NEWS-A [217] and NEWS-CS [163] have been shown to have comparable validity and reliability, and the former has been translated and used in international studies on environmental determinants of PA [218].

For this PhD research program, 12 destination proximity items that were comparable across the two cities—Brisbane, Australia and Hong Kong, China – were used. These perceived destination proximity items included the following types of destination categories: *supermarket, café/restaurant, fruit and vegetable shop, fast food restaurant, public transport, public park, post office, library, primary school, childcare centre, chemist/drug store and*

doctor/medical centres. These 12 types of destinations have been shown to influence older adults' walking behaviour [53, 61]. Participants were asked to report the time needed to walk to the nearest destination of a specific type using a 5-point scale (i.e., 1: 1-5 minute, 2: 6-10 minute, 3: 11-20 minute, 4: 20-30 minute and 5: 30+ minute).

3.3.2 Outcome variables

This PhD program of research used older adults' self-reported weekly frequency and minutes of walking for transport and recreation as outcome variables. The outcome variables were categorised into **location non-specific** and **within-neighbourhood** walking for transport and recreation based on the context and the instrument used to measure them. While location non-specific weekly minutes of walking for different purposes were measured in the HABITAT as well as Hong Kong Elderly study, weekly frequency and minutes of within-neighbourhood walking for different purposes were measured only in the Hong Kong Elderly study.

To measure location non-specific walking, the Chinese version of the International PA Questionnaire – Long Form (IPAQ-LC, last 7 days) [219] was used in Hong Kong, while comparable items focusing on walking for transport and recreation only were used in the HABITAT study [220].

The interviewer-administered IPAQ-LC assessed participants' location non-specific minutes of walking for transport and recreation in the last seven days. The IPAQ-LC items measuring weekly minutes of location non-specific walking for transport have shown acceptable test-retest reliability (Intraclass Correlation Coefficients (ICC)= 0.88) and criterion validity based on the association with a diary measure (r = 0.70). Additionally, IPAQ-LC items measuring

weekly minutes of location non-specific walking for recreation have also been found to have acceptable test-retest reliability (ICC = 0.83) and criterion validity based on the association with a corresponding diary measure (r = 0.48). The observed levels of reliability and validity of the IPAQ-LC among Chinese older adults mirror those of studies across multiple countries [221].

HABITAT used a modified version of the Active Australian Survey [222], which was comparable to items of the IPA long form [223], to collect participants' self-reported data on walking for different purposes in the last 7 days. A study examining the test reliability of items of the Active Australia Survey found that the ICC coefficients ranged from 0.60 to 0.80, indicating an acceptable level of reproducibility [222]. The Neighbourhood Walking Questionnaire—Chinese version for seniors (NWQ-CS) [163] was used to assess participants' weekly frequency and minutes of within-neighbourhood walking for transport and recreation among Hong Kong older adults. The NWQ-CS is an interviewer-administered questionnaire based on the walking section of the NPAQ [224,225]. The NWQ-CS defined a neighbourhood as an area within 10-15-minute walk from home. Participants were first asked to report whether they walked within their neighbourhood during the usual week to get to a destination or from somewhere (i.e., for transportation purposes) or for health-enhancing or exercise purposes (i.e., walking for recreation). If participants responded affirmatively, they were asked to report the weekly frequency and duration (i.e., minutes) of walking for transport and recreation within their neighbourhood.

The NWQ-CS has shown acceptable reliability for measuring weekly frequency (ICC (95% Confidence Interval (CI)): 0.76 (0.65,).85)) and minutes (ICC (95%CI): 0.54 (0.39, 0.70) of within-neighbourhood walking for transport. The corresponding criterion validity based on the associations of the NWQ-CS and diary measures of frequency and minutes of within-neighbourhood walking for transport was acceptable (r =0.43 and r=0.56, respectively).

Additionally, the NWQ-CS has demonstrated acceptable reliability for measuring weekly frequency (ICC (95% (CI)): 0.78 (0.67, 0.83) and minutes (ICC (95% CI): 0.68 (0.55, 0.81) of within-neighbourhood walking for recreation. Criterion validity based on the associations of NWQ-CS with diary measures of frequency and minutes was high (r = 0.83 and r = 0.68, respectively).

3.3.3 Location non-specific walking for transport and recreation

For the purpose of this PhD research program, the following location non-specific walking for transport and recreation outcome variables were computed: 1) total weekly minutes of walking for transport (equivalent to days walked for transport multiplied by the average minutes of walking in a day); and 2) total weekly minutes of walking for recreation. These variables were used in all three studies included in this thesis (see Chapters 4 to 6).

3.3.4 Weekly frequency and minutes of within-neighbourhood walking for transport and recreation

Only the Hong Kong study assessed weekly frequency and minutes of within-neighbourhood walking for transport and recreation. The following outcome variables were created: 1) weekly frequency of walking for transport and recreation (number of days ranging from 0 to 7 days); 2) total weekly minutes of walking for transport within the neighbourhood (equivalent to days walked for transport multiplied by the average minutes of walking in a day); and 3) total weekly minutes of within neighbourhood walking for recreation. Only study 2 (Chapter 5) and study 3 (Chapter 6) examined the associations between perceived destination accessibility types and weekly frequency and minutes of within-neighbourhood walking for transport and recreation.

3.3.4 Moderators—Perceived neighbourhood non-destination characteristics

According to the socio-ecological models of PA, availability of, or proximity to, destinations alone are necessary but not sufficient to influence walking behaviour [53, 70]. This is because other neighbourhood non-destination characteristics can moderate the associations between access to destinations and individuals' walking behaviour in their neighbourhoods [53, 61, 62]. Therefore, this thesis examined 9 perceived non-destination characteristics of the neighbourhood environment as potential moderators of destination accessibility-walking associations (within the context of Hong Kong), which was the third aim of this research program. Perceived non-destination characteristics that were considered as moderators included: *physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic hazards; traffic speed; crime; sitting facilities; and the presence of bridge/overpass.* These were measured using subscales or items derived from the NEWS-CS [163]. The items assessed participants' perceptions of their neighbourhood environment on a 4-point Likert scale – (*1. Strongly disagree; 2. Somewhat disagree; 3. Somewhat agree and 4. Strongly agree*). The NEWS-CS has shown to have good factorial validity and a moderate-to-good test-retest reliability ranging from 0.52 to 0.77 for the examined subscales, except for 'the presence of people' having a low ICC of 0.37. However, the overall percentage of agreement was high (87%), indicating an acceptable level of reliability and construct validity [163].

3.3.5 Covariates

Participants' socio-demographic data and neighbourhood socioeconomic status were considered as covariates where appropriate.

3.3.5.1 Participants' socio-demographic data

Data on participants' sociodemographic characteristics, including age, gender and education, were collected via a self-administered questionnaire in Brisbane and an interviewer-administered questionnaire in Hong Kong.

Age as a covariate

The age distribution and type of available data were different across the two studies. Participants in the HABITAT study had their age recorded as a continuous variable, while the participants in the Hong Kong Elderly study had their age recorded as a categorical variable (65-74 years; 75+ years). Also, participants in the HABITAT study were younger than their counterparts in the Hong Kong Elderly study. Specifically, all the participants in HABITAT were aged between 65 and 70 years. In contrast, 66.9 % of the participants in the Hong Kong Elderly sample were between 65 and 74 years, and 33.1% were 75 years and over (See Table 1). For the above reasons, participants' age was treated as a study-specific covariate.

Gender as a covariate

The distribution of gender was similar across the studies. Forty per cent (40%) of the HABITAT study sample and 41.5% of the Hong Kong Elderly participants were male (See Table 1). Gender was treated as a covariate in all the three studies with female as the reference category.

Education as a covariate

The educational system across the two study locations was different and, as a consequence, educational levels were coded differently across studies. In the HABITAT study,

participants' educational attainment had nine categories and these categories were collapsed into three categories including, secondary or less (48.6%); trade, certificate and diploma (33.9%); and bachelor or higher (17.5%). In the Hong Kong Elderly study sample, thirteen per cent (13.0 %) of the participants had no formal education, 47.9% had primary education and 39.0% had secondary or higher education. The levels were collapsed into a binary classification—less than secondary education and secondary education or higher. Participants' educational attainment was treated as a study-specific covariate in the analyses.

3.3.5.2 Neighbourhood socio-economic status

The two studies derived NSES using similar information from the census data. In the HABITAT study, NSES was computed based on median monthly household income, with 58.1% of selected administrative units being categorised as high-SES and 41.9% as low-SES [226]. In the Hong Kong Elderly study, NSES was derived from the census data based on the median monthly household income and percentage of owner-occupiers of the administrative units falling within the catchment areas of the selected EHCs, with 49.6% selected administrative units representing high-SES areas and 50.4% representing low-SES areas. In each study, high-SES areas were coded as 1 and low-SES areas were coded as 0. NSES was used as a covariate in the studies with the low-SES category being considered as a reference group.

Table 1 below reports differences and similarities across the data sets from the two studies based on aspects of the methodology, participants' socio-demographic characteristics and measures. These include the sampling procedure, data collection types, response rate, study measures and participants' sociodemographic information. Details of the information presented in Table 1 have been provided in the subsequent sections of the thesis.

Table 1: Data description

Study characteristics	**Brisbane (N=793)**	**Hong Kong (N= 484)**
Methodological aspects		
Sampling	Two-stage stratified by area-level SES	Two-stage stratified by area-level SES and walkability
Survey administration	Mailed, self-completed	Interviewer-administered
Response rate, %	67.3	78.0
Measure of destination accessibility	12 comparable items measuring perceived distance to destinations from the NEWS-Abbreviated	12 comparable items measuring perceived distance to destinations from the NEWS for Chinese Seniors
Measure of total walking for transport	Items comparable to those of the IPAQ – Long Form	Items from the Chinese version of the IPAQ – Long Form
Measure of total walking for recreation	Items comparable to those of the IPAQ – Long Form	Items from the Chinese version of the IPAQ – Long Form
Measures of within-neighbourhood walking	Not available	Items from the NWQ – CS
Moderator	Not available	9 perceived non-destination characteristics measuring participants' perceptions of their neighbourhood environment
Sample characteristics		
Number of neighbourhoods	197.0	32.0
Number of participants	793.0	484.0
Area-level SES, % high	58.1	49.6
Gender, % male	40.0	41.5
Educational attainment, %		
Less than secondary	41.3	60.9
Secondary equivalent or higher	58.7	39.1
Age category, %		

65-74 years	100.0	66.9
> 75 years	0.0	33.1

Note. SES =Socio-economic status; NEWS = Neighbourhood Environment Walkability Scale; IPAQ = International Physical Activity Questionnaire; NWQ-CS = Neighbourhood Walkability Questionnaire- Chinese version for Seniors.

3.4 Section Three: Statistical data analyses

This section describes the different statistical analytical strategies carried out to investigate specific aims within this thesis. This PhD research program follows a PhD by Publication format. It comprises seven separate chapters. Three chapters (chapter 4, 5 and 6) are empirical studies. Each empirical study was designed to address specific research aims within this thesis. To minimise repetition within this thesis, the readers are encouraged to review the detailed methodologies in the respective studies/chapters.

3.4.1 Study One

The first study, presented in Chapter 4 of this thesis, had four aims and each aim required a specific statistical technique to address it. Generalised estimating equations (GEE) with binomial variance and logit link function were used to address the first aim —, namely, to examine differences in perceived destination accessibility between the two cities based on an analysis of responses to binary destination accessibility items (denoting the presence or absence of a specific destination within 5-, 10- and 20-minute walk from home). Latent class analysis was used to address the second aim, which was to identify perceived destination accessibility types (latent classes of older adults based on a combination of different destination items) within a 5-, 10- and 20-minute walk from home in the two cities. Zero-inflated negative regression models with robust standard errors were used to address the third aim – i.e., to examine the differences in levels of walking for transportation and recreation in the two cities. Finally, multinomial logistic regression models within the latent class analysis framework were used to examine the relationships between perceived destination accessibility types within a 5-, 10- and 20-minute walk from home, and NSES. All regression analyses were adjusted for gender. Due to the

hierarchical nature of the datasets, all models were adjusted for neighbourhood-level clustering arising from the two-stage sampling design. Analyses for the first and third aims were conducted in Stata 15.1 (StataCorp LLC, College Station, TX), while analyses to address the second and last aims were conducted in Mplus (version 7.4) [227].

3.4.2 Study Two

The second study is presented in Chapter 5. This study built upon the findings from the first study by using the latent classes of perceived destination accessibility types as the main exposure variable (independent variable). The primary aim of this study was to investigate the associations between the latent classes of neighbourhood destination accessibility within a 5-, 10- and 20-minute walk from home and older adults' self-reported walking for transport and recreation in the two cities. Study 2 also examined the associations of latent classes of neighbourhood destination accessibility with Hong Kong older adults' self-reported weekly frequency and minutes of within-neighbourhood walking for transport and recreation. Based on the distribution of the outcome variables, two types of regression models were used to achieve the study aims. These were generalised linear models with negative binomial variance and logarithmic link function and zero-inflated negative binomial regression models. All the models were estimated using a robust clustered standard error to account for the multilevel component of the datasets. Additionally, all models were adjusted for gender. All the analyses were conducted in Stata 15.1 (StataCorp LLC, College Station, TX, USA).

3.4.3 Study Three

The third study is reported in Chapter 6. This study builds on some of the findings reported in Studies 1 and 2 by investigating the moderating effects of neighbourhood non-destination characteristics on the associations between the latent classes of destination accessibility within 5-, 10- or 20-minute walk from home and walking for transport and recreation in older adults within the context of Hong Kong. The latent classes of perceived destination accessibility types derived in Study 1 were used as the main independent variables. This study examined nine neighbourhood non-destination characteristics as potential moderators. These characteristics were treated as continuous variables in the analyses. The study investigated the moderating effect on the associations in two ways: (1) by examining individual neighbourhood non-destination characteristics as potential moderators or (2) by examining the latent profiles of nine non-destination characteristics as potential moderators.

Latent profile analysis was used to derive profiles of perceived neighbourhood types based on the nine non-destination characteristics. A detailed description of the analysis has been provided in the method section of Chapter 6. Two types of regression models: generalised linear models with negative binomial variance and logarithmic link function, and zero-inflated negative binomial regression models were used based on the distribution of the outcome variables. All the models were estimated using a robust clustered standard error to account for the multilevel component of the data sets. Participants' socio-demographic characteristics – namely, age and gender - were used as covariates in the models. While the latent profile analysis was conducted in Mplus (version 8) [227], all the analyses pertaining to an examination of associations and

moderating effects on those associations were conducted in Stata 15.1 (StataCorp LLC, College Station, TX).

3.5 Summary

The present chapter provides detailed information about the methodology employed to address the aims of this PhD research program. The subsequent chapters (Chapter 4, 5 and 6) present the empirical studies, with each study investigating specific aims. Two chapters (Chapter 4 and 5) representing the first and second empirical studies respectively have been published in high-quality peer-reviewed journals. The manuscript of the third study is being prepared for submission in a peer-reviewed journal.

CHAPTER 4

WALKING BEHAVIOUR AND PATTERNS OF PERCEIVED ACCESS TO NEIGHBOURHOOD DESTINATIONS IN OLDER ADULTS FROM A LOW-DENSITY (BRISBANE, AUSTRALIA) AND AN ULTRA-DENSE CITY (HONG KONG, CHINA)

CHAPTER 4: WALKING BEHAVIOUR AND PATTERNS OF PERCEIVED ACCESS TO NEIGHBOURHOOD DESTINATIONS IN OLDER ADULTS FROM A LOW-DENSITY (BRISBANE, AUSTRALIA) AND AN ULTRA-DENSE CITY (HONG KONG, CHINA)

This chapter presents the first empirical study of this PhD research program. The study investigated the differences in levels of walking and perceived destination accessibility between older adults living in a low-density city (Brisbane, Australia) and ultra-dense city (Hong Kong, China). Specifically, the study examined between-city differences in levels of perceived destination accessibility to specific types of destinations, profiles of destination accessibility and amounts of walking for transportation and recreation purposes in older adults. The study has undergone scientific peer review and has been published in a high-quality international scientific journal— namely, *Cities*.

Citation:

Boakye-Dankwa, E., Nathan, A., Barnett, A., Busija, L., Lee, R. S. Y., Pachana, N., Turrell, G., Cerin, E. (2019). Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China). *Cities*, *84*, 23-33. Doi: https://doi.org/10.1016/j.cities.2018.07.002

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CHAPTER 5

ASSOCIATIONS BETWEEN LATENT CLASSES OF PERCEIVED NEIGHBOURHOOD DESTINATION ACCESSIBILITY AND WALKING BEHAVIOURS IN OLDER ADULTS OF A LOW-DENSITY (BRISBANE, AUSTRALIA) AND A HIGH-DENSITY (HONG KONG, CHINA) CITY

CHAPTER 5: ASSOCIATIONS BETWEEN LATENT CLASSES OF PERCEIVED NEIGHBOURHOOD DESTINATION ACCESSIBILITY AND WALKING BEHAVIOURS IN OLDER ADULTS OF A LOW-DENSITY (BRISBANE, AUSTRALIA) AND A HIGH-DENSITY (HONG KONG, CHINA) CITY

This chapter presents the second empirical study of this PhD research program. The second study extended the findings from the first study (see Chapter 2) to investigate the associations between the latent classes of perceived neighbourhood destination accessibility ("Good access", "Limited access" and "Poor access") and weekly minutes of location non-specific walking for transport and recreation in older adults residing in a low-density (Brisbane, Australia) and a high-density city (Hong Kong, China). Additionally, the study examined the relationships between the latent classes of perceived destination accessibility and weekly frequency and minutes of within-neighbourhood walking for transport and recreation in older adults living in the high-density city (Hong Kong). The study has gone through peer review and has been published by a high-quality international journal in physical activity – namely, *Journal of Aging and Physical Activity* (JAPA).

Citations:

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CHAPTER 6

MODERATING EFFECT OF PERCEIVED NEIGHBOURHOOD NON-DESTINATION CHARACTERISTICS ON THE ASSOCIATIONS BETWEEN PERCEIVED DESTINATION ACCESSIBILITY TYPES AND WALKING BEHAVIOUR IN HONG KONG CHINESE OLDER ADULTS

CHAPTER 6: MODERATING EFFECT OF PERCEIVED NEIGHBOURHOOD NON-DESTINATION CHARACTERISTICS ON THE ASSOCIATIONS BETWEEN PERCEIVED DESTINATION ACCESSIBILITY TYPES AND WALKING BEHAVIOUR IN HONG KONG CHINESE OLDER ADULTS

This chapter presents the third empirical study of this PhD research program. The third study extended the findings from the first and the second studies (see Chapter 4 and 5) to investigate the moderating effects of nine perceived neighbourhood non-destination characteristics (*physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic hazards; traffic speed; safety from crime; sitting facilities; and presence of bridges/overpass*) on the associations between perceived neighbourhood destination accessibility within a 5-, 10- and 20-minute walk from home and self-report measures of overall (location non-specific) and within-neighbourhood walking for transport and recreation in older adults within the context of Hong Kong. The manuscript for this study is being under preparation for submission in a peer review journal.

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6.1 Abstract

Introduction: This study investigated the moderating effects of nine perceived neighbourhood non-destination characteristics (*physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic hazards; traffic speed; safety from crime; sitting facilities; and presence of bridges/overpass*) on the associations between perceived destination accessibility types within a 5-, 10- and 20-minute walk from home and self-report measures of total (location non-specific) and within-neighbourhood walking for transport and recreation in older adults (aged 65+ years) within the context of Hong Kong.

Methods: Perceived neighbourhood destination accessibility types were derived from latent class analysis of perceived distance to 12 destinations from home. The destination measures came from an extant epidemiological study on Hong Kong Chinese older adults conducted in 2007-2008 to investigate the associations of neighbourhood environmental attributes with physical activity in older adults. Single perceived neighbourhood non-destination attributes and their combined profiled were considered as potential moderators (continuous variable) of the associations between perceived destination accessibility and walking for transport or recreation.

Results: Several perceived neighbourhood non-destination characteristics independently or conjointly moderated the associations of perceived destination accessibility types with self-report measures of walking for transport and recreation in older adults. A significantly larger number of moderating effects was found for walking for recreation than walking for transport. Several of these moderating effects were in the opposite direction to those expected. The perceived

presence of sitting facilities and safety from crime were among the moderators that augmented the positive effects of destination accessibility on walking.

Conclusion: This study suggests that policymakers in Hong Kong and other ultra-dense metropolises should not only focus on optimising or improving the distance between destinations and residents' homes but also focus on improving other neighbourhood non-destination features such as crime safety, connectivity and availability of sitting facilities that may facilitate older adults' walking for different purposes.

Keyword: Environmental moderators, latent profile analysis, latent class analyses, perceived destination accessibility types, walking for transport and recreation.

6.2 Introduction

Regular physical activity is an important lifestyle behaviour for improving health and well-being in people, especially in older adults (people aged ≥ 65 years) [4, 44]. Walking, whether for transport (e.g., walking to or from a place within a neighbourhood) or for recreation (walking for the purpose of leisure or exercise, such as walking a pet), is the most common form of physical activity (PA) [4, 40]. Walking has been identified globally as a robust public health strategy to increase PA levels in people, particularly in older adults [4, 44]. This is because walking has been shown to benefit numerous health outcomes. Regular participation in walking can lower the incidence of cardiovascular diseases and some cancers [33]; can improve cognitive health [29, 30]; can lower depressive symptoms [31]; and can reduce mortality rate [32]. These findings suggest that creating opportunities for older adults to walk can help them achieve the global recommended levels of PA and, thus, improve their health and wellbeing.

Ecological models of health behaviour postulate that individuals' PA behaviour such as walking is largely influenced by multilevel interacting features of the neighbourhood environment [70]. The neighbourhood environment is an important setting for environmental interventions aimed at increasing older adults' walking because older adults spend more time in their neighbourhood than other age groups due to retirement and ageing-related challenges, such as a decline in walking speed and a decrease in distance they can travel by foot [4, 15, 78, 79, 101, 228]. The neighbourhood environment can be described in terms of built and social environment characteristics [68, 70, 76], which contribute to shaping residents' walking behaviour in a unique way [53, 61, 76, 80, 81, 84, 229]. The built environment includes physical features such as shops, restaurants, public transport stops, public parks, sitting facilities/benches, physical barriers and bridges, while the social environment includes characteristics such as safety

from crime and the presence of people in the street [68, 70, 76, 97, 183]. Characteristics of the neighbourhood environment can serve as facilitators or barriers to older adults' walking behaviour as well as moderators of the associations between other neighbourhood features and walking [53, 61]. For example, whether older adults will engage in walking for transport to a shop or for recreation to a park may depend on other neighbourhood characteristics, such as aesthetics, physical barriers, safety from crime and traffic as well as the presence of people [53, 61, 62, 85].

Destination accessibility is a key neighbourhood built environment feature that has been shown to influence walking behaviour in older adults [53, 85]. That is, neighbourhoods with high destination accessibility within a short walking distance from home encourage more walking than those with low access to destinations [53, 230, 231]. Access to destinations can be defined as the interaction between individual- and neighbourhood-level characteristics [80, 86, 87]. More specifically, neighbourhood destination accessibility can be defined as the availability of destinations such as shops, public transport stops and hospitals within walking distance from home, and the ease of reaching them by any means of transport (e.g., by walking and/or public transport or by a private vehicle) [80, 86, 87]. To access a local destination, residents may need to consider several non-destination characteristics, such as trip distance, pedestrian infrastructure, physical barriers, presence of people, safety from crime and traffic, and aesthetics, influencing their decision of whether to walk or not to walk to that destination [53, 61, 232]. This may explain why a study on destination accessibility and walking behaviour among older adults in Hong Kong identified that the level of neighbourhood safety moderated the association between objectively-measured access to public transport stops and overall walking for transport and between objectively-assessed availability of various recreational destinations and within-

neighbourhood walking for transport [85]. Additionally, pedestrian infrastructure moderated the association of within-neighbourhood walking for transport and availability of commercial destinations [85]. Further, in a study from the USA, safety from traffic moderated the association between the availability of recreational facilities and weekly minutes of walking for recreation [183].

Destination accessibility can be quantified objectively or via self-reports [53]. Although there is a mismatch between objective and self-report measures [88], self-report measures may be more appropriate to consider when assessing neighbourhood destination accessibility in older adults [53]. This is because older adult populations are heterogeneous regarding their level of mobility and physical capacity [12, 89]. For example, even within the same neighbourhood, individuals may report different accessibility experiences for a particular destination (e.g., access to the supermarket) based on their perception of several factors [90, 91]. Nonetheless, a study published in the U.S. found that older adults who resided in a neighbourhood with a profile that they perceived to be more activity-friendly appeared to walk more than their counterparts [204]. Additionally, Boakye-Dankwa and colleagues found that Australian and Hong Kong older adults reported different levels of perceived destination accessibility (i.e., different neighbourhood destination accessibility profiles) based on self-reported walking time from home to 12 types of destinations [231]. That study found no significant positive associations between perceived destination accessibility types and weekly frequency and minutes of walking for transport and recreation among Hong Kong participants [230]. Although Hong Kong is a compact, ultra-dense and destination-rich city with high levels of walking among older adults, the general lack of significant associations between perceived destination accessibility and weekly minutes of overall and within-neighbourhood walking for different purposes may indicate that having good

access to mixes of destinations in the neighbourhood is important and necessary, but not necessarily sufficient to promote higher levels of within-neighbourhood walking. This suggests that there may be some potential factors that may moderate destination accessibility-walking associations in Hong Kong older adults.

Although the importance of moderators of destination accessibility-PA associations has been emphasised [53, 233], the vast majority of studies has not examined them or focussed solely on socio-demographic characteristics (e.g., sex) as potential moderators [53, 62]. Only a handful of studies have attempted to examine neighbourhood characteristics, such as aesthetics, pedestrian infrastructure, safety from crime and traffic, as potential moderators of destination accessibility and walking association [53, 62, 85, 90]. These studies employed variable-centred analytical techniques, such as regression models, to identify moderators [53, 61, 62, 188]. For example, a study found that the presence of stray animals moderated the relationship between the availability of public transport stops and walking in Hong Kong older adults [85], while another study conducted in the U.S. found no significant moderators of the association between perceived safety and total walking for transport [183]. Apart from the dearth of studies on this issue, the failure to identify significant moderators may be due to the fact that past studies employed variable-centred approaches to investigate single neighbourhood characteristics as moderators [53, 61, 62]. The employment of person-centred analytical approaches, such as latent profile analysis, may increase the power to detect moderating effects [188]. This is because these approaches can address multicollinearity problems associated with highly correlated environmental moderators (e.g., pedestrian infrastructure and traffic safety) and more efficiently reveal higher-order interaction effects. Distinct profiles of potential environmental moderators

obtained from latent profile analyses can then be investigated as multi-dimensional categorical moderators of destination accessibility-walking associations.

To the best of our knowledge, no known studies have examined perceived neighbourhood non-destination attributes, such as safety from crime and traffic, aesthetics, presence of people, physical barriers and pedestrian infrastructure, separately or collectively, as moderators of the associations between perceived destination accessibility types (profiles) and overall or within-neighbourhood walking for transport or recreation in older adults. Thus, the main purpose of this study was to address this knowledge gap by building upon a recently published study on the associations of perceived destination accessibility types with overall and within-neighbourhood walking for transport or recreation in Hong Kong older adults [230].

The first aim of this study was to investigate the moderating effects of single perceived neighbourhood non-destination characteristics on the associations of the latent classes of perceived destination accessibility types (i.e., "Good access", "Limited access" and "Poor access") within a 5-, 10- or 20-minute walking time from home with weekly frequency and minutes of walking for transport and recreation among Hong Kong Chinese older adults. The second aim was to examine the combined characteristics (i.e., the latent profiles of nine perceived neighbourhood non-destination characteristics) as moderators of the associations of the latent classes of perceived destination accessibility with overall or within-neighbourhood walking for different purposes. We hypothesised that the relationship between destination accessibility and walking outcomes would be more positive and stronger in the presence of single and latent profiles of perceived neighbourhood non-destination characteristics known to support engagement in walking. Specifically, we hypothesised that residents of neighbourhoods with better destination accessibility would be more likely to report higher levels of overall and

within-neighbourhood walking for different purposes than residents of neighbourhoods with poorer destination accessibility if they also reported living in a neighbourhood with more activity-friendly profiles of non-destination characteristics or higher levels of single activity-friendly non-destination characteristics (higher levels of aesthetics, traffic safety, safety from crime, street connectivity; better pedestrian infrastructure; more sitting facilities and people in the streets; better street connectivity; and fewer physical barriers to walking).

6.3 Methods and materials

6.3.1 Study settings: Design and participants

This study used secondary data from a study on Hong Kong Chinese older adults (aged 65+ years) collected in 2007-2008 to investigate the relationships between neighbourhood environmental characteristics and older adults' PA [163, 218]. The detailed methodology has been explained elsewhere [163, 218]. Briefly, a multi-stage sampling approach was used to sample 484 older adults from four Hong Kong Elderly Health Centres (EHC) and who resided in 32 pre-selected neighbourhoods. These neighbourhoods were stratified by neighbourhood-level socioeconomic status (NSES) and transport-related walkability to maximise the range of neighbourhood built environment characteristics while controlling for NSES based on median household income. As a result, approximately 50% of participants resided in high SES neighbourhoods. The data used in this study were collected using an interviewer-administered questionnaire. The response rate was 78%. Ethical approval was received from the Department of Health Ethics Committee (Hong Kong SAR) and the Human Research Ethics Committee for Non-Clinical Faculties of the University of Hong Kong [85].

6.3.2 Measures

6.3.2.1 Walking for transport and walking for recreation (outcome variables)

The full Chinese version of the International Physical Activity Questionnaire – Long Form (IPAQ-LC) was used to assess location non-specific weekly minutes of walking for transport and recreation [219]. Further, the Neighbourhood Walking Questionnaire- Chinese version for seniors (NWQ-CS) was used to assess the weekly frequency and minutes of within-neighbourhood walking for transport and recreation [134, 224].

6.3.2.2 Perceived destination accessibility types (main exposure variable)

Table 1 presents the latent classes of perceived destination accessibility types (i.e., "Good access", "Limited access" and "Poor access") including their corresponding item-response probabilities. The methodology used to derive these latent classes has been detailed elsewhere [231]. Briefly, latent class analysis was employed to derive perceived destination accessibility types using self-report data on the presence of 12 neighbourhood destinations within a 5-, 10-, and 20-minute walk from home. The latent class indicators (perceived access to 12 destinations) were extracted from the Neighbourhood Environment Walkability Scale (NEWS) [139] for Chinese Seniors (NEWS-CS) [163]. The items assessed participants' perception of walking time from home to the following destinations: supermarket, café/restaurant, fruit and vegetable shop, fast food restaurant, public transport, public park, post office, library, primary school, childcare centre, chemist/drug store and doctor/medical centres. The items were scored on a 5-point scale (i.e., 1: 1-5 minute, 2: 6-10 minute, 3: 11-20 minute, 4: 20-30 minute and 5: 30+ minute). The original responses on each destination items were categorised into three distinct perceived-

distance variables denoting whether a destination was perceived to be available (score of 1) or not available (score of 0) within a 5-, 10-, and 20-minute walk from home.

Table 1. Latent classes and item-response probabilities of perceived destination accessibility (perceived destination accessibility types) by walking distance categories

Perceived access within a 5-minute walk from home		
Destinations	High Access 50.2% (n= 243)	Poor Access 49.8% (n= 241)
Supermarket	0.876	0.195
Café/Restaurant	0.890	0.160
Fruit &Vegetable Shop	0.662	0.087
Fast Food Restaurant	0.691	0.087
Public Transport	0.845	0.376
Public Park	0.677	0.346
Post Office	0.388	0.065
Library	0.161	0.045
Primary School	0.618	0.248
Childcare Centre	0.693	0.285
Chemist/Drug Store	0.876	0.108
Doctor/Medical Centre	0.744	0.109
Perceived access within a 10-minute walk from home		
	High Access 79.3% (n= 384)	Poor Access 20.7% (n= 100)
Supermarket	0.972	0.512
Café/Restaurant	0.986	0.457
Fruit &Vegetable Shop	0.872	0.235
Fast Food Restaurant	0.882	0.188
Public Transport	0.975	0.645
Public Park	0.804	0.456
Post Office	0.649	0.043
Library	0.315	0.163
Primary School	0.838	0.286
Childcare Centre	0.818	0.291
Chemist/Drug Store	0.937	0.387
Doctor/Medical Centre	0.896	0.292

Perceived access within a 20-minute walk from home		
	High Access 88.2% (n= 427)	Limited Access 11.8% (n= 57)
Supermarket	1.000	0.886
Café/Restaurant	0.992	0.875
Fruit &Vegetable Shop	0.993	0.515
Fast Food Restaurant	0.970	0.460
Public Transport	0.995	0.951
Public Park	0.937	0.720
Post Office	0.889	0.166
Library	0.556	0.293
Primary School	0.931	0.434
Childcare Centre	0.901	0.477
Chemist/Drug Store	0.988	0.709
Doctor/Medical Centre	0.973	0.712

6.3.2.3 Socio-demographic characteristics (covariates)

Participants' socio-demographic characteristics - age and gender - were collected and used in the analysis as covariates.

6.3.2.4 Perceived neighbourhood non-destination characteristics (moderators)

This study used nine perceived neighbourhood non-destination characteristics as potential moderators of associations between perceived destination accessibility types and walking behaviour in older adults. These perceived neighbourhood non-destination characteristics were assessed using the NEWS-CS [163] and included the following multi-item or single-item subscales: physical barriers to walking (3 items); pedestrian infrastructure (3 items); aesthetics (4 items); the presence of people (2 items); traffic hazards (6 items); traffic speed (2 items); safety from crime (3 items); sitting facilities (1 item); and presence of bridges/overpass (1 item). These subscales assessed participants' perception of their neighbourhood environment on a 4-point

Likert scale with 1 indicating strong disagreement and 4 indicating strong agreement. Scores on multi-item subscales represented the mean ratings on the relevant items. The nine perceived neighbourhood non-destination characteristics were treated as continuous variables in the analyses.

6.3.3 Data analyses

Descriptive statistics were computed for all variables. Two types of regression models were used to estimate the moderation effects of non-destination perceived neighbourhood characteristics on the associations between perceived destination accessibility types and walking behaviours: (1) generalised linear models with negative binomial variance and logarithmic link functions; and (2) zero-inflated negative binomial regression models. Each model was estimated using a robust clustered standard error estimator to account for the multilevel structure of the datasets (persons nested within neighbourhoods). These models are appropriate for positively skewed count outcome variables (weekly frequency or minutes of walking for transport or recreation). We employed negative binomial rather than Poisson models because the walking outcomes had a much larger variance than their mean, suggesting overdispersion [234]. Zero-inflated models were used when the number of zero values exceeded that expected by a traditional negative binomial distribution as determined by the results of the Vuong test [235]. Participants' socio-demographic characteristics—age and gender—were used as covariates in the models.

6.3.3.1 Moderation analysis

We examined the moderating effects using two types of analytical strategies: (1) single perceived neighbourhood non-destination attributes were considered as potential moderators (continuous variable) of the associations between perceived destination accessibility and walking for transport or recreation; and (2) combined perceived neighbourhood non-destination attributes (i.e., latent profiles of perceived non-destination characteristics) (categorical variable) were considered as a potential moderator of the associations. **Figure 1** illustrates the conceptual model underpinning the moderating effects of perceived neighbourhood non-destination characteristics on the relationships between perceived destination accessibility and walking for transport or recreation.

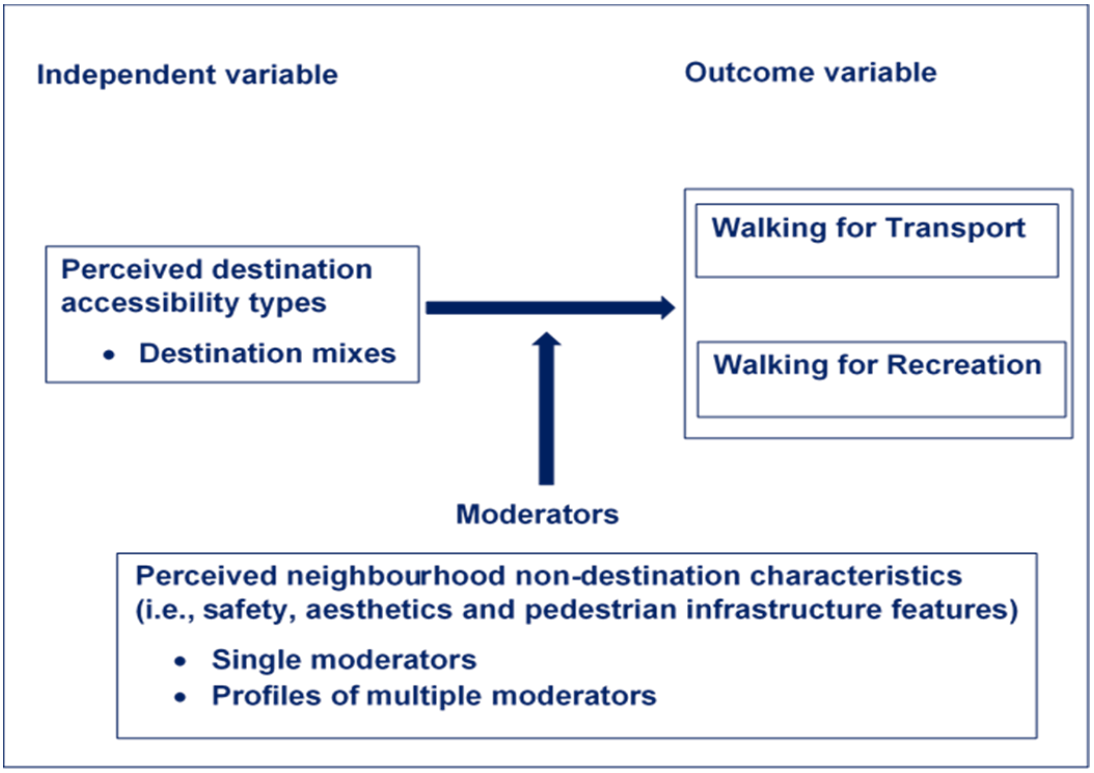

Fig. 1. Model illustrating the moderation effects of perceived neighbourhood non-destination characteristics on the association between perceived destination accessibility types and walking behaviour

6.3.3.2 Analysis 1- single perceived neighbourhood non-destination characteristics as moderators

Single perceived neighbourhood non-destination characteristics were treated as moderators of the association between perceived destination accessibility types and walking outcomes. We examined the moderating effects of each of the nine perceived non-destination characteristics separately. This was done by determining the statistical significance of a specific destination accessibility type by moderator interaction term (p-value < .05) included in a regression model defined as follows:

A specific walking outcome = $\text{intercept}_1 + b_1$ (Age) + b_2 (Gender) + b_3 (LCA_i) + b_4 (Mod) + b_5 (LCA*Mod) + e

where LCA_i represented a categorical independent variable with two levels (i.e., 0 indicating "poor/limited accessibility" (reference group) and 1 denotes "good accessibility") and **Mod** was a continuous moderator variable - perceived neighbourhood non-destination attribute. When there was evidence of moderation effects (i.e., a significant interaction term, *p*-value < 0.05 at 95% confidence interval), we probed the interaction term further by conducting a *simple slope analysis* to assess the direction of the moderating effects [236]. This was achieved by estimating the linear combination of the regression coefficients for the independent variable (LCA) and the moderator at meaningful values of that moderator - the mean value, a standard deviation above the mean and a standard deviation below the mean (or minimum/maximum theoretical value, when appropriate) [236]. If the moderation effect was not significant, the interaction term was dropped from the regression model.

6.3.3.3 Analysis 2- combined perceived neighbourhood non-destination characteristics as moderators

To achieve our second aim, we conducted a latent profile analysis (LPA) to derive a categorical latent variable (i.e., perceived neighbourhood types) of nine perceived neighbourhood non-destination subscales in Mplus 8 [227]. LPA derived homogeneous and mutually exclusive latent profiles that maximised between-profile variances and minimised within-profile variances. Each latent profile represented a group of participants characterised by unique patterns of nine perceived neighbourhood non-destination characteristics [188]. Latent profile solutions of 1 to 4 were conducted iteratively, and several selection criteria based on quantitative and qualitative assessments were employed to select profiles that best represented the data structure. These included model fit indices, such as Bayesian Information Criterion (BIC) (models with lower BIC values were preferred) [237], and entropy values [238]. Entropy values are bounded between 0 and 1. A value near 1 indicates a high degree of separation between the identified profiles. We also used the Lo-Mendell-Rubin likelihood ratio test (LMR) [188, 239] which compares two latent profile solutions (e.g., k-profile and (k+1)-profile) and produces a *p*-value. A significant *p*-value < .05 indicates that a k-profile solution should be rejected in favour of a (k+1)-profile solution [239]. Finally, we examined average posterior probabilities per latent classes. These evaluate the classification uncertainty in each latent class. Average posterior probabilities of at least 0.70 are recommended for all latent profile analyses [240]. Further, we considered qualitative criteria to complement the above quantitative selection criteria. These included substantive interpretability and theoretical meaningfulness of latent profiles [188, 241]; model parsimony (models with fewer parameters were preferred) [188]; and

sample size per latent class (i.e., latent classes with ≥ 5% of the total sample were considered viable) [204, 242].

Participants were classified into their respective latent profiles based on their largest posterior probability of latent profile membership [188]. Substantive interpretation of latent profiles was based on the examination of the item-profile relationships [188, 243]. Based on the selection criteria listed above, we selected a 3-profile solution to represent the participants' perceived neighbourhood environment pertaining to non-destination characteristics. The latent profiles were represented by a categorical variable with 3 levels- "Good perception"; "Reasonable perception"; and "Poor perception". Each profile was labelled based on a qualitative examination of the patterns of responses. This latent profile solution was depicted on a two-dimensional graph that represented the estimated mean z-score values on the y-axis and perceived neighbourhood non-destination characteristics on the x-axis. The categorical latent profile (i.e., perceived neighbourhood non-destination profiles) was treated as a moderator variable with the "poor perception" profile being considered as the reference group in the model. We assessed the moderating effects by examining the interaction of the two categorical variables: perceived destination accessibility types (i.e., 1= "Good access" and 0= "Poor access") by perceived neighbourhood environment types (i.e., 2 = "Good perception", 1= "Reasonable perception", 0 = "Poor perception). The analyses followed the same above-mentioned analytical procedure carried out to investigate single continuous moderator. Significant moderating effects of the categorical latent profile variable were probed by estimating the associations of destination accessibility with a specific walking outcome across categories of the moderator (0 = "Poor perception", 1= "Reasonable perception", and 2= "Good perception"). While the latent profile analysis was conducted in Mplus (version 8) [227], all the analyses pertaining to an examination

of associations and moderating effects on those associations were conducted in Stata 15.1 (StataCorp LLC, College Station, TX).

6.4 Results

Table 2 shows the descriptive statistics of the study variables - participants' socio-demographic characteristics, perceived neighbourhood non-destination attributes and walking outcomes. Approximately 33% of the sample was represented by participants aged 75 years and over, and 58.5% of participants were females. On average, weekly minutes and frequency of walking for transportation were higher than those for recreation.

Table 2. Descriptive statistics for participants' sociodemographic characteristics, perceived neighbourhood non-destination environmental characteristics and walking for transport and recreation

Variable	%	Mean (SD)	Median (IQR)
Sociodemographic characteristics			
Age			
65- 74 years	66.9		
75+ years	33.1		
Gender			
Female	58.5		
Males	41.5		
Perceived neighbourhood non-destination characteristics (theoretical range)			
Physical barriers to walking (1-4)		1.39 (0.58)	
Pedestrian infrastructure (1-4)		3.83 (0.35)	
Aesthetics (1-4)		2.14 (0.63)	
Presence of people (1-4)		3.72 (0.53)	
Traffic hazards (1-4)		1.67 (0.60)	
Traffic speed (1-4)		1.95 (0.79)	
Safety from crime (1-4)		1.32 (0.55)	

Sitting facilities (1-4)	2.83 (1.15)	
Presence of bridges/overpass (1-4)	2.04 (1.22)	
Outcome variables		
Walking for transport:		
Location non-specific weekly minutes of walking	569.5 (452.2)	420.0 (630.0)
Within-neighbourhood weekly minutes of walking	254.2 (262.1)	75.0 (290.0)
Within-neighbourhood weekly frequency of walking	11.5 (10.7)	7.0 (8.0)
Walking for recreation:		
Location non-specific weekly minutes of walking	331.1 (379.5)	210.0 (360.0)
Within-neighbourhood weekly minutes of walking	243.8 (330.6)	120.0 (420.0)
Within-neighbourhood weekly frequency of walking	4.5 (4.4)	5.5 (7.0)

Notes: %: values in percentage; SD: Standard deviation; IQR: Interquartile range

6.4.1 Aim 1: Single perceived neighbourhood non-destination characteristics as moderators

Table 3 presents the statistically significant moderating effects of single perceived neighbourhood non-destination characteristics on the relationships between perceived destination accessibility and weekly frequency/minutes of location non-specific and within-neighbourhood walking for transport and recreation.

None of the nine perceived neighbourhood non-destination characteristics moderated the associations of perceived destination accessibility within a 5-minute walk from home with location non-specific transportation and recreational walking. The same held true for perceived destination accessibility within a 10-minute walk from home and location non-specific walking for transport. In contrast, perceived safety from crime and the presence of bridges/overpass moderated the associations of perceived destination accessibility within a 10-minute walk from home and walking for recreation in those who engaged in this type of walking (Table 3). Specifically, only participants reporting above average levels of safety from crime showed a significant positive association between perceived destination accessibility and non-zero weekly

minutes of location non-specific walking for recreation (Table 4). Recreational walkers living in a safe neighbourhood with good access to destinations accumulated 31% more weekly minutes of walking than recreational walkers reporting living in a safe neighbourhood with poor access to destinations (Table 4). Similar findings were observed with respect to the perceived presence of bridges/overpasses as a moderator, although the actual association between destination accessibility and non-zero minutes of walking for recreation only approached significance (p = .066; Table 4).

Perceived presence of people was the only significant moderator of the association between location non-specific walking for transport and perceived destination accessibility within a 20-minute walk from home (Table 3). The association between the latter two variables was significant and negative only among residents who perceived above average levels of presence of people in the neighbourhood (Table 4). Furthermore, four significant interaction effects on non-zero weekly minutes of walking for recreation were observed between this measure of destination accessibility and neighbourhood non-destination characteristics (Table 3). Recreational walkers who reported higher levels of physical barriers to walking tended to show a more positive association between destination accessibility and non-zero weekly minutes of walking for recreation (Table 4). The same was true for recreational walkers reporting higher levels of traffic hazards and safety from crime. In contrast, recreational walkers who perceived lower levels of pedestrian infrastructure showed a positive association between destination accessibility within a 20-minute walk from home and non-zero weekly minutes of walking for recreation (Table 4). Perceived traffic hazards were also a significant moderator of the associations between destination accessibility within a 20-minute walk from home and the odds of not engaging in location non-specific walking for recreation (interaction term: OR = 0.33 95%

CI: 0.15, 0.75, *p*=.008). Older adults reporting living in neighbourhoods with higher levels of traffic hazards showed a negative association between destination accessibility and the odds of not engaging in location non-specific walking for recreation (OR = 0.43 95% CI: 0.21, 0.89, *p* = .022). That is, they were more likely to engage in walking for recreation. Lower levels of traffic hazards were associated with increasingly more positive but not significant associations between destination accessibility and the odds of not engaging in walking for recreation (association at mean value of perceived traffic hazard: OR = 0.83 95%CI: 0.41, 1.66, *p* = .599; association at mean – 1 SD value of traffic hazard: OR = 1.60 95%CI: 0.61, 4.16, *p* = .338).

No significant moderators of the associations between perceived destination accessibility within a 5-minute walk from home and weekly minutes of within-neighbourhood walking for transport and recreation were found. Perceived pedestrian infrastructure and aesthetics moderated the association between perceived destination accessibility within a 10-minute walk from home and non-zero weekly minutes of walking for recreation within the neighbourhood (Table 3). Only recreational walkers reporting below average levels of pedestrian infrastructure and aesthetics showed a positive association between destination accessibility within a 10-walk from home and non-zero weekly minutes of walking for recreation in the neighbourhood (Table 4). No significant moderators of the associations between destination accessibility within-10 minutes walking distance from home and within-neighbourhood walking for transport were found.

Perceived physical barriers to walking moderated the association between perceived destination accessibility within a 20-minute walk from home and non-zero weekly minutes of within-neighbourhood walking for transport in those who engaged in this type of walking (Table 3). A significant and positive association was observed only if residents perceived their

neighbourhoods to have above average levels of physical barriers to walking (Table 4). That is, among those who perceived high levels of physical barriers to walking, walkers for transport living in a neighbourhood with good access to destinations within a 20-minute walk from home accumulated 27% more weekly minutes of walking for transport than walkers for transport living in a neighbourhood with limited access to destinations. Additionally, four perceived neighbourhood non-destination characteristics—pedestrian infrastructure, presence of people, traffic hazards and sitting facilities—moderated the association between perceived destination accessibility within 20-minute walk from home and non-zero weekly minutes of within-neighbourhood walking for recreation (Table 3). Recreational walkers who reported higher levels of pedestrian infrastructure, presence of people and sitting facilities tended to show more negative associations between perceived destination accessibility within a 20-minute walk from home and weekly minutes of within-neighbourhood walking for recreation, while those who reported below average levels of these environmental attributes tended to show positive associations (Table 4). For example, recreational walkers who perceived their neighbourhood to have good access to destinations within a 20-minute walk from home accumulated 25% more weekly minutes of within-neighbourhood walking for recreation than their counterparts with limited access to destinations, provided they perceived below average levels of the presence of people in their neighbourhood (Table 4). In contrast, the moderating effect of perceived traffic hazards on the associations of perceived destination accessibility within a 20-minute walk from home and non-zero weekly minutes of within-neighbourhood walking for recreation was in the opposite direction (Table 3).

Perceived sitting facilities moderated the association between destination accessibility within a 5-minute walk from home and weekly frequency of within-neighbourhood walking for

transport (Table 3). Only participants reporting above-average levels of perceived sitting facilities displayed a significant positive association between this specific destination accessibility measure and frequency of within-neighbourhood walking for transport (Table 4). Perceived safety from crime exhibited similar moderating effects on frequency of walking for recreation (Table 3), whereby residents of safe neighbourhoods with good access to destination within a 5-minute walk from home accumulated 47% more weekly frequency of within-neighbourhood walking for recreation than their counterparts living in safe neighbourhoods with poor access to destinations.

Finally, perceived traffic hazards moderated the association between perceived destination accessibility within a 10-minute walk from home and weekly frequency of within-neighbourhood walking for transport (Table 3). Only participants reporting below-average traffic hazards showed a negative association between perceived destination accessibility within 10-minute walk from home and weekly frequency of within-neighbourhood walking for transport (Table 4). None of the nine perceived neighbourhood non-destination characteristics moderated the association between perceived destination accessibility within a 10-minute walk from home and weekly frequency of within-neighbourhood walking for recreation, and between perceived destination accessibility within a 20-minute from home and weekly frequency of within-neighbourhood walking for different purposes (Table 3).

Table 3. Significant moderating effects: Single perceived neighbourhood non-destination characteristics as moderators of associations between destination accessibility and walking for transport and recreation

	Location non-specific minutes of walking	
	Walking for transport	**Walking for recreation**
	GLM	ZINB
	Weekly minutes of walking	Non-zero weekly minutes of walking (Negative binomial model)
Significant Interaction	e^b (95% CI), *p*	e^b (95% CI), *p*
Destination accessibility within a 10-minute walk from home		
Good access (reference: poor access) by perceived:		
Safety from crime		**1.42 (1.06, 1.89), 0.017**
Presence of bridges/overpass		**1.17 (1.01, 1.37), 0.042**
Destination accessibility within a 20-minute walk from home		
Good access (reference: limited access) by perceived:		
Presence of people	**0.56 (0.39, 0.82), 0.002**	
Physical barriers to walking		**1.42 (1.05, 1.93), 0.024**
Pedestrian infrastructure		**0.45 (0.22, 0.92), 0.029**
Traffic hazards		**2.03 (1.48, 2.78), <0.001**
Safety from crime		**1.43 (1.02, 2.00), 0.036**

	Within-neighbourhood minutes of walking	
	Walking for transport	**Walking for recreation**
	Non-zero weekly minutes of walking (Negative binomial model)	Non-zero weekly minutes of walking (Negative binomial model)
	e^b (95% CI), *p*	e^b (95% CI), *p*
Destination accessibility within a 10-minute walk from home		
Good access (reference: poor access) by perceived:		
Pedestrian infrastructure		**0.57 (0.36, 0.89), 0.013**
Aesthetics		**0.78 (0.61, 0.99), 0.044**
Destination accessibility within a 20-minute walk from home		
Good access (reference: limited access) by perceived:		
Physical barriers to walking	**1.37 (1.08, 1.74), 0.009**	
Pedestrian infrastructure		**0.57 (0.37, 0.88), 0.011**
Presence of people		**0.58 (0.45, 0.75), <0.001**
Traffic hazards		**1.43 (1.05, 1.95), 0.024**
Sitting facilities		**0.80 (0.66, 0.97), 0.025**

	Within-neighbourhood frequency of walking (times/week)	
	Walking for transport	**Walking for recreation**
	e^b (95% CI), *p*	e^b (95% CI), *p*
Destination accessibility within a 5-minute walk from home		

Good access (reference: poor access) by perceived:		
Sitting facilities	**1.17 (1.02, 1.33), 0.021**	
Safety from crime		**1.61 (1.02, 2.54), 0.043**
A 10-minute walk from home		
Good access (reference: poor access) by perceived:		
Traffic hazards	**1.44 (1.09, 1.91), 0.011**	

Notes: GLM: Generalised linear model; ZINB: Zero-inflated negative binomial; OR: Odds ratio; e^b: antilogarithm of regression coefficient; CI: confidence intervals of regression estimate; all estimates adjusted for age and gender.

Table 4: **Probing moderating effects: Single perceived neighbourhood non-destination moderators of associations between destination accessibility and walking for transport and recreation**

Destination accessibility types by a single perceived moderator	Walking for Transport (Weekly minutes of walking)	Walking for Recreation (Non-zero weekly minutes of walking)
	e^b (95% CI), *p*	e^b (95% CI), *p*
Location non-specific weekly minutes of walking		
Destination accessibility within a 10-minute walk		
Good access (reference: poor access) by perceived safety from crime		
+1 SD from the mean of perceived safety from crime (1.87)		**1.31 (1.05, 1.62), 0.017**
mean of perceived safety from crime (1.32)		1.07 (0.91, 1.27), 0.409

minimum theoretical value of perceived safety from crime (1.00)		0.96 (0.79, 1.17), 0.690
Good access (reference: poor access) by perceived presence of bridges/overpass		
+1 SD from the mean of perceived presence of bridges/overpass (3.26)		1.29 (0.98, 1.68), 0.066
mean of perceived presence of bridges/overpass (2.04)		1.06 (0.88, 1.27), 0.546
minimum theoretical value of perceived presence of bridges/overpass (1.00)		0.90 (0.71, 1.14), 0.364
Destination accessibility within a 20-minute walk		
Good access (reference: limited access) by the presence of people		
maximum theoretical value of presence of people (4.00)	**0.79 (0.65, 0.96), 0.017**	
mean of presence of people (3.72)	0.93 (0.78, 1.11), 0.425	
-1 SD from the mean of the presence of people (3.19)	1.26 (0.94, 1.68), 0.117	
Good access (reference: limited access) by perceived physical barriers to walking		
+1 SD from the mean of perceived physical barriers to walking (1.97)		1.26 (0.94, 1.68), 0.121
mean of perceived physical barriers to walking (1.39)		1.03 (0.76, 1.39), 0.870
minimum theoretical value of perceived physical barriers to walking (1.00)		0.89 (0.62, 1.29), 0.552
Good access (reference: limited access) by perceived pedestrian infrastructure		
maximum theoretical value of perceived pedestrian infrastructure (4.00)		0.91 (0.66, 1.12), 0.559
mean of perceived pedestrian infrastructure (3.83)		1.04 (0.80, 1.36), 0.767
-1 SD from the mean of perceived pedestrian infrastructure (3.48)		**1.38 (1.01, 1.87), 0.042**
Good access (reference: limited access) by perceived traffic hazards		
+1 SD from the mean of perceived traffic hazards (2.27)		**2.11 (1.60, 2.80), <0.001**

mean of perceived traffic hazards (1.67)	**1.38 (1.12, 1.70), 0.002**
-1 SD from the mean of perceived traffic hazards (1.07)	0.91 (0.68, 1.21), 0.500
Good access (reference: limited access) by perceived safety from crime	
+1 SD from the mean of perceived safety from crime (1.87)	1.25 (0.93, 1.69), 0.137
mean of perceived safety from crime (1.32)	1.03 (0.80, 1.18), 0.822
minimum theoretical value of perceived safety from crime (1.00)	0.92 (0.69, 1.23), 0.572

Within-neighbourhood weekly minutes of walking

	Walking for Transport	Walking for Recreation
	e^b (95% CI), *p*	e^b (95% CI), *p*
Destination accessibility within a 10-minute walk		
Good access by perceived pedestrian infrastructure		
maximum theoretical value of perceived pedestrian infrastructure (4.00)		1.10 (0.85, 1.42), 0.479
mean of perceived pedestrian infrastructure (3.83)		1.21 (0.95, 1.55), 0.124
-1 SD from the mean of perceived pedestrian infrastructure (3.48)		**1.48 (1.11, 1.96), 0.007**
Good access by perceived aesthetics		
+1 SD from the mean of perceived aesthetics (2.78)		1.06 (0.83, 1.37), 0.634
mean of perceived aesthetics (2.14)		1.24 (0.97, 1.59), 0.085
-1 SD from the mean of perceived aesthetics (1.51)		**1.45 (1.05, 2.01), 0.024**
Destination accessibility within a 20-minute walk		
Good access by perceived physical barriers to walking		
+1 SD from the mean of perceived physical barriers to walking (1.97)	**1.27 (1.07, 1.50), 0.005**	
mean of perceived physical barriers to walking (1.39)	1.06 (0.85, 1.31), 0.623	

minimum theoretical value of perceived physical barriers to walking (1.00)	0.93 (0.70, 1.24), 0.640
Good access by perceived pedestrian infrastructure	
maximum theoretical value of perceived pedestrian infrastructure (4.00)	0.82 (0.67, 1.01), 0.068
mean of perceived pedestrian infrastructure (3.83)	0.91 (0.75, 1.10), 0.318
-1 SD from the mean of perceived pedestrian infrastructure (3.48)	1.10 (0.86, 1.40), 0.436
Good access by the presence of people	
maximum theoretical value of the presence of people (4.00)	**0.80 (0.66, 0.98), 0.027**
mean of the presence of people (3.72)	0.94 (0.79, 1.11), 0.443
-1 SD from the mean of the presence of people (3.19)	**1.25 (1.02, 1.53), 0.028**
Good access by perceived traffic hazards	
+1 SD from the mean of perceived traffic hazards (2.27)	1.31 (0.99, 1.73), 0.060
mean of perceived traffic hazards (1.67)	1.06 (0.90, 1.23), 0.499
-1 SD from the mean of perceived traffic hazards (1.07)	0.85 (0.70, 1.04), 0.115
Good access by perceived sitting facilities	
+1 SD from the mean of perceived sitting facilities (3.98)	**0.75 (0.58, 0.96), 0.023**
mean of perceived sitting facilities (2.83)	0.97 (0.83, 1.12), 0.665
-1 SD from the mean of perceived sitting facilities (1.69)	1.25 (0.94, 1.66), 0.129

Within-neighbourhood weekly frequency of walking		
	Walking for Transport	Walking for Recreation
	e^b (95% CI), *p*	e^b (95% CI), *p*
Destination accessibility within a 5-minute walk		
Good access by perceived sitting facilities		

+1 SD from the mean of perceived sitting facilities (3.98)	**1.29 (1.04, 1.60), 0.022**	
mean of perceived sitting facilities (2.83)	1.08 (0.92, 1.26), 0.329	
-1 SD from the mean of perceived sitting facilities (1.69)	0.91 (0.73, 1.12), 0.370	
Good access by perceived safety from crime		
+1 SD from the mean of perceived safety from crime (1.87)		**1.47 (1.04, 2.07), 0.027**
mean of perceived safety from crime (1.32)		1.13 (0.97, 1.32), 0.113
minimal theoretical value of perceived safety from crime (1.00)		0.97 (0.82, 1.15), 0.759
Destination accessibility within a 10-minute walk		
Good access by perceived traffic hazards		
+1 SD from the mean of perceived traffic hazards (2.27)	1.15 (0.92, 1.44), 0.219	
mean of perceived traffic hazards (1.67)	0.92 (0.76, 1.12), 0.423	
-1 SD from the mean of perceived traffic hazards (1.07)	**0.74 (0.56, 0.99), 0.042**	

Note: e^b: antilogarithm of regression coefficient; CI: confidence intervals of regression estimate; all estimates adjusted for age and gender.

6.4.2 Aim 2: Combined perceived neighbourhood non-destination characteristics as moderators

Table 5 reports a 3-profile solution of the perceived neighbourhood non-destination characteristics. The latent profiles—"Poor perception", "Reasonable perception" and "Good perception"—were labelled based on the patterns of the estimated means of the nine perceived neighbourhood non-destination characteristics. Thus, the "poor perception" profile represented participants living in neighbourhoods characterised by the highest estimated means of perceived physical barriers to walking, traffic hazards, traffic speed and crime safety; moderate estimated means of aesthetics, sitting facilities and presence of bridges/overpass; and the lowest estimated means of pedestrian infrastructure and presence of people. The "reasonable perception" latent profile represented residents living in neighbourhoods characterised by the lowest estimated means of physical barriers to walking, aesthetics, traffic hazards, traffic speed and presence of bridges/overpass; moderate estimated means of presence of people, crime safety and sitting facilities; and the highest estimated means for pedestrian infrastructure. Finally, the "good perception" profile represented participants living in neighbourhoods characterised by moderate estimated means of physical barriers to walking, pedestrian infrastructure, traffic hazards, traffic speed, crime safety and sitting facilities; and highest estimated means of aesthetics, presence of people and presence of bridges/overpass. The estimated means of the latent profiles are presented in Figure 2. The y-axis represents the estimated mean z-score values and the x-axis represents the perceived neighbourhood non-destination characteristics.

Table 5: Estimated means and standard errors for a 3-profile solution of perceived neighbourhood non-destination characteristics

Perceived neighbourhood non-destination characteristics	Poor perception (n = 85, 17.6%)	Reasonable perception (n = 232, 47.9%)	Good perception (n = 167, 34.5%)
	Mean (S.E)	Mean (S.E)	Mean (S.E)
Physical barriers to walking	0.278 (0.118)	-0.090 (0.067)	-0.017 (0.073)
Pedestrian infrastructure	-0.440 (0.137)	0.109 (0.064)	0.075 (0.067)
Aesthetics	0.053 (0.102)	-0.095 (0.062)	0.103 (0.085)
Presence of people	-1.941 (0.090)	0.383 (0.023)	0.459 (0.020)
Traffic hazards	0.533 (0.113)	-0.118 (0.063)	-0.108 (0.077)
Traffic speed	0.082 (0.113)	-0.037 (0.064)	0.010 (0.078)
Safety from crime	0.597 (0.144)	-0.129 (0.059)	-0.126 (0.066)
Sitting facilities	-0.030 (0.112)	0.002 (0.067)	0.012 (0.076)
Presence bridges/overpass	-0.312 (0.084)	-0.762 (0.017)	1.203 (0.034)

Notes: S.E: Estimated standard error

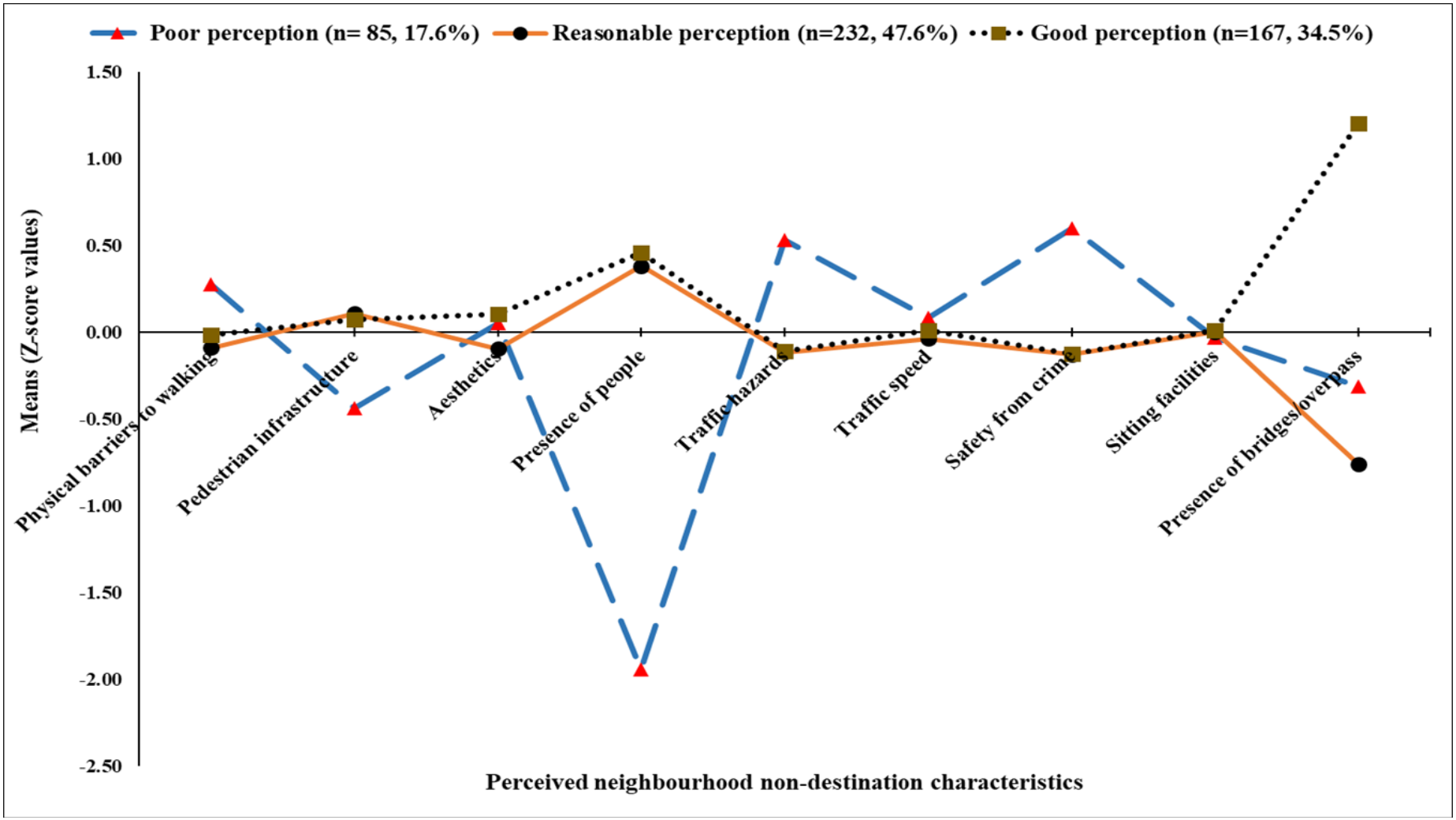

Fig. 2. Estimated mean plot from a 3-profile solution of perceived neighbourhood non-destination characteristics in older adults in Hong Kong. A z-score of +1.0 indicates an estimated mean of 1 SD above the sample mean, and a z-score of -1.0 indicates an estimated mean of 1SD below the sample mean

Table 6 shows the moderating effects of combined perceived neighbourhood non-destination characteristics (latent profiles of nine perceived neighbourhood non-destination characteristics) on the associations between perceived destination accessibility and weekly minutes of walking for transport and recreation.

The latent profiles of neighbourhood non-destination characteristics moderated the association between perceived destination accessibility within a 20-minute walk from home and weekly minutes of location non-specific of walking for transport (Table 6). A significant positive association between perceived destination accessibility and weekly minutes of location non-specific walking for transport was observed only in participants with poor perceptions of neighbourhood non-destination characteristics (Table 7). Residents with good access to destinations within a 20-minute walk from home accumulated 54% more weekly minutes of location non-specific walking for transport than those with limited access to destinations only when they perceived their neighbourhoods as having poor non-destination characteristics as defined in this study (Tables 5 and 7). The latent profiles of neighbourhood non-destination characteristics did not moderate the associations between perceived destination accessibility within a 5- and 10-minute walk from home and weekly minutes of location non-specific walking for transport. Also, they did not moderate the associations of destination accessibility within a 10- and 20-minute walk from home and weekly minutes of location non-specific walking for recreation. However, they moderated the association between perceived destination accessibility within a 5-minute walk from home and non-zero weekly minutes of location non-specific walking for recreation (Table 6). Only residents with a ‘reasonable perception’ profile showed a significant negative association between perceived destination accessibility and non-zero weekly minutes of location non-specific walking for recreation (Table 7).

The latent profiles of neighbourhood non-destination characteristics did not moderate the associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and weekly minutes or frequency of within-neighbourhood walking for transport. However, they moderated the associations of perceived destination accessibility within a 10- and 20-minute walk from home and non-zero weekly minutes of within-neighbourhood walking for recreation (Table 6). Only participants with a 'Poor perception' profile showed significant positive associations between perceived destination accessibility within a 10- and 20-minute walk from home and non-zero weekly minutes of within-neighbourhood walking for recreation (Table 7). Also, those with a 'Good perception' profile showed a significant negative association between perceived destination accessibility within a 20-minute walk from home and non-zero minutes of within-neighbourhood walking for recreation (Table 7). Latent profiles of neighbourhood non-destination characteristics did not moderate the associations between destination accessibility and frequency of within-neighbourhood walking for recreation.

Table 6: Significant moderating effects: Combined perceived neighbourhood non-destination characteristics profiles as moderators of associations between destination accessibility and weekly minutes of walking for transport and recreation

Weekly minutes of location non-specific walking	
	Walking for transport (Generalised linear model)
Significant interaction	e^b (95%), p-value
Destination accessibility within a 20-minute walk from home	
Good access by:	
Good perception	**0.54 (0.30, 0.96), 0.035**
Reasonable perception	**0.53 (0.33, 0.83), 0.006**
	Walking for recreation (Zero-inflated negative binomial model)
	Non-zero weekly minutes of walking (Negative binomial model)
	e^b (95%), p-value
Destination accessibility within a 5-minute walk from home	
Good access by:	
Good perception	0.79 (0.47, 1.34), 0.385
Reasonable perception	**0.57 (0.35, 0.94), 0.027**
	Weekly minutes of within-neighbourhood walking
	Walking for recreation (Zero-inflated negative binomial model)
	Non-zero weekly minutes of regular walking (Negative binomial model)
	e^b (95%), p-value

Destination accessibility within a 10-minute walk from home	
Good access by:	
Good perception	0.69 (0.39, 1.23), 0.212
Reasonable perception	**0.57 (0.36, 0.90), 0.015**
Destination accessibility within a 20-minute walk from home	
Good access by:	
Good perception	**0.40 (0.25, 0.63), <0.001**
Reasonable perception	**0.44 (0.26, 0.75), 0.002**

Notes: e^b: antilogarithm of regression coefficient; CI: confidence intervals of regression estimate; all estimates adjusted for age and gender.

Table 7. Probing the moderating effects: Combined perceived neighbourhood non-destination characteristics profiles as moderators of associations between destination accessibility and weekly minutes of walking for transport and recreation

Characteristics	**Walking for transport (weekly minutes) (GLM)**	**Walking for recreation (non-zero weekly minutes) (ZINB)**
	e^b (95% CI), *p*	e^b (95% CI), *p*
Location non-specific weekly minutes of walking		
Destination accessibility within a 5-minute walk		
Good access by Good perception		1.16 (0.87, 1.53), 0.310
Good access by Reasonable perception		**0.83 (0.70, 0.99), 0.045**
Good access by Poor perception		1.45 (0.94, 2.26), 0.093

Destination accessibility within a 20-minute walk		
Good access by Good perception	0.83 (0.60, 1.15), 0.263	
Good access by Reasonable perception	0.81 (0.62, 1.06), 0.121	
Good access by Poor perception	**1.54 (1.02, 2.32), 0.039**	
	Within-neighbourhood weekly minutes of walking	
Destination accessibility within a 10-minute walk		
Good access by Good perception		1.24 (0.76, 2.02), 0.394
Good access by Reasonable perception		1.02 (0.73, 1.42), 0.921
Good access by Poor perception		**1.78 (1.28, 2.48), 0.001**
Destination accessibility within a 20-minute walk		
Good access by Good perception		**0.75 (0.57, 0.97), 0.029**
Good access by Reasonable perception		0.83 (0.58, 1.18), 0.301
Good access by Poor perception		**1.87 (1.30, 2.68), 0.001**

Notes: e^b: antilogarithm of regression coefficient; CI: confidence intervals of regression estimate; all estimates adjusted for age and gender

6.5 Discussion

This study extends the findings from our previous research [230, 231] by examining the moderating effects of nine perceived neighbourhood non-destination characteristics (*physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic hazards; traffic speed; safety from crime; sitting facilities; and presence of bridges/overpass*) on the associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and self-report measures of total (location non-specific) and within-neighbourhood walking for transport and recreation in older adults within the context of Hong Kong.

This is the first study to investigate a wide range of perceived neighbourhood non-destination characteristics as moderators of associations between perceived destination accessibility types and self-report measures of walking for transport and recreation in older adults. Importantly, this study also examined the moderating effects of profiles (i.e., combinations) of nine perceived neighbourhood non-destination characteristics on the association between perceived destination accessibility and walking outcomes. Although the results did not fully support our hypotheses, our findings suggest that some perceived neighbourhood non-destination characteristics could independently or conjointly moderate destination-walking associations in older adults.

6.5.1 Moderators of associations between perceived destination accessibility and walking for transport

As noted in our previous study, no associations between perceived destination accessibility and total walking for transport were observed [230]. The same was true for within-neighbourhood walking for transport, with the exception of perceived destination accessibility within a 5-minute walk from home with respect to non-zero weekly minutes of

walking for transport for which a negative association was observed. This lack of associations motivated the present study.

In general, very few significant moderating effects of perceived neighbourhood non-destination characteristics on the associations of perceived destination accessibility with walking for transport were observed. None of the nine single perceived neighbourhood non-destination characteristics or their combined profiles moderated the associations of perceived destination accessibility within a 5- and 10-minute walk from home with weekly minutes of overall and within-neighbourhood walking for transport. Only one of the nine perceived neighbourhood non-destination attributes moderated each of the associations between perceived destination accessibility within a 5- and 10-minute walk from home and weekly frequency of within-neighbourhood walking for transport, and of perceived destination accessibility within a 20-minute walk from home with overall walking for transport and within-neighbourhood weekly minutes of walking for transport in those who engaged in this behaviour. No moderating effects were observed in relation to destination accessibility and the odds of engaging in within-neighbourhood walking for transport. Finally, profiles of perceived neighbourhood destination attributes moderated only one association between perceived destination accessibility (within a 20-minute walk from home) and walking for transport (overall weekly minutes).

Perceived presence of people in the street moderated the association between perceived destination accessibility within a 20-minute walk from home and weekly minutes of overall walking for transport. Specifically, a significant and negative association between perceived accessibility and weekly minutes of walking for transport was observed only in those who reported the highest levels of perceived presence of people in the street. Although this finding appears to be counterintuitive, it is possible that destination-dense and overly crowded streets may act as a deterrent to engaging in higher levels of walking for transport

among older adults who, typically, experience mobility issues. They may especially find it challenging to carry items from their shopping trips for longer distances (20-minute walk from home). A previous study reported that objectively-measured barriers to walking, such as the presence of hawkers in the street, attenuated the positive effects of having good access to shops in the neighbourhood on walking for transport among Hong Kong older adults [85]. It is also possible that the actual level of destination accessibility of neighbourhoods perceived to have good access to destinations and a large number of pedestrians in the streets may be higher than that of neighbourhoods perceived to have good access to destination but not large numbers of pedestrians in the streets. Extreme levels of destination accessibility may actually reduce the total amount of walking required for activities of daily living.

Perceived physical barriers to walking was the only neighbourhood perceived attribute to moderate the association between perceived accessibility within a 20-minute walking from home and weekly minutes of within-neighbourhood walking for transport in those who walked. Contrary to our hypothesis, we observed that only residents of neighbourhoods perceived to have above-average levels of physical barriers to walking accumulated 27% more weekly minutes of walking for transport when they reported having good as opposed to limited access to destinations. Older adults who live in areas with many physical barriers to walking may not engage in utilitarian walking in their neighbourhood unless they have a lot of destinations of daily living. In the absence of such destinations, they may travel to other areas by public transport and engage in walking for transport in those areas (i.e., engage in walking for transport outside the neighbourhood). Another possible explanation could be that residents of destination-rich neighbourhoods who report physical barriers to walking in their local areas neighbourhood may consider choosing longer routes to destinations that are less physically challenging (with milder slopes or more even terrain).

Perceived sitting facilities moderated the relationship of destination accessibility with within-neighbourhood weekly frequency of walking for transport in the expected direction. Specifically, participants with above-average levels of perceived sitting facilities reported 29% higher weekly frequency of within-neighbourhood walking for transport if they perceived to have good rather than poor access to destinations. Sitting facilities have been previously found to be positively associated with walking for transport in another cohort of Hong Kong older adults [168]. As they provide older adults the opportunity to rest and socialise during their utilitarian trips, sitting facilities may encourage more frequent walking for transport in this age group when the local area provides access to destinations of daily living.

Perceived traffic hazards moderated the association between destination accessibility within a 10-minute walk from home and frequency of within-neighbourhood walking for transport in the opposite direction to what expected. Thus, older adults with below-average levels of perceived traffic hazards showed a negative association between destination accessibility and frequency of within-neighbourhood walking for transport. However, this association was weak, barely significant and, perhaps, due to chance. Yet, given that traffic hazards are typically higher in busy areas with commercial facilities that attract customers, it is possible that the 'good access' neighbourhoods with low levels of traffic hazards were typified by lower-quality (unattractive) destinations.

The only moderating effect of the latent profile—"Poor perception", "Reasonable perception" and "Good perception"—of the nine perceived neighbourhood non-destination characteristics on destination accessibility-walking for transport associations were not in the expected direction. Residents of neighbourhoods characterised by a poor perception of non-destination characteristics accumulated 54% more weekly minutes of location non-specific walking for transport when they perceived having good rather than limited access to

destinations within a 20-minute walk from home. These effects were not observed among participants who reported having more favourable perceptions of their neighbourhood. Neighbourhoods perceived to have poor characteristics had higher levels of barriers to walking, traffic hazards and safety from crime, fewer people in the street and worse pedestrian infrastructure than their counterparts. Older residents of such areas may engage in substantial amounts of walking for transport only if they have destinations of daily living in their vicinity. In contrast, older adults living in areas with more people and with fewer physical challenges to walking (i.e., better pedestrian infrastructure and fewer physical barriers and traffic hazards) may engage in walking for transport not only for essential daily living purposes, which would require having good access to commercial destinations and services, but also to visit other people or go to recreational places. Thus, the difference in amount of walking between older adults living in neighbourhoods with 'good access' versus 'limited access' to services and desirable non-destination characteristics may be small.

6.5.2 Moderators of associations between perceived destination accessibility and walking for recreation

A substantially greater number of significant moderation effects were observed with respect to measures of walking for recreation than walking for transport. Safety from crime and the presence of bridges/overpass moderated the associations between perceived destination accessibility within a 10-minute walk from home and weekly minutes of location non-specific walking for recreation. On average, among participants who engaged in recreational walking activities, residents who resided in neighbourhoods with above-average levels of perceived safety from crime and had good access to destinations within a 10-minute walk from home accumulated 31% more weekly minutes of location non-specific walking for recreation than those with poor access to destinations. Similar moderating effects of

perceived safety from crime were observed on the associations of destination accessibility within 20-minute walking distance from home with weekly minutes of overall walking for recreation in regular walkers and of destination accessibility within a 5-minute walk from home with within-neighbourhood frequency of walking for recreation. This suggests that perceived neighbourhood safety from crime is an essential factor for older adults to engage in walking, especially for recreation. These findings support our hypothesis that the associations between destination accessibility and walking would be more positive in the presence of neighbourhood characteristics encouraging walking. Although the evidence in the literature is mixed, higher levels of perceived safety from crime have been shown to promote walking behaviours in older adults [53, 62, 83].

Perceived presence of bridges/overpass—a measure of connectivity—also moderated the association between perceived destination accessibility within a 10-minute walk from home and walking for recreation in a similar manner to safety from crime, although the association between destination accessibility and overall walking for recreation (in those who engaged in this activity) at above-average levels of perceived presence of bridges/overpasses only approached significance ($p = 0.066$). These findings corroborate those of previous studies suggesting that neighbourhoods with higher levels of perceived safety from crime, perceived connectivity and perceived access to destinations within a walking distance from home encourage walking behaviours in older adults [62, 83, 146].

Three additional perceived neighbourhood non-destination characteristics—physical barriers to walking, pedestrian infrastructure and traffic hazards— moderated the associations between perceived destination accessibility within a 20-minute walk from home and overall walking for recreation. Contrary to our hypothesis that the associations between destination accessibility and walking would be stronger and positive for activity-friendly neighbourhood non-destination characteristics, we observed an opposite trend of moderating effects for these

perceived neighbourhood attributes. Similar unexpected moderating effects of the latter two neighbourhood non-destination characteristics and of perceived aesthetics were observed with respect to weekly minutes of within-neighbourhood walking for recreation. These unexpected effects could be due to the fact that residents of neighbourhoods with poorer non-destination characteristics (high levels of traffic hazards and physical barriers to walking, poor pedestrian infrastructure and low levels of environmental aesthetics) need other incentives to walk for recreation, these being access to various destinations of daily living. Thus, the presence of a variety of destinations in the neighbourhood may become a reason for engaging in any or greater volumes of recreational walking when other aspects of the environment are not enticing. Residents of neighbourhoods with undesirable environmental characteristics may prefer to walk for recreation within commercials areas, such as shopping centres, supermarkets and restaurants where there may be fewer physical barriers, better pedestrian infrastructure, more interesting and aesthetically pleasing things to see and no traffic-related issues.

Two additional perceived neighbourhood non-destination characteristics—the presence of people in the street and sitting facilities— showed moderating effects on the associations between perceived destination accessibility within a 20-minute walk from home and weekly minutes of within-neighbourhood walking for recreation of opposite direction to those expected. Above-average levels of perceived presence of people in the street yielded negative associations, and below-average levels positive associations, between destination accessibility and within-neighbourhood walking for recreation. Neighbourhoods with few destinations (i.e., with limited destination accessibility) that are visited by many people are likely to be areas for leisure-time activities, such as popular parks or beaches, which are attractive places for recreational walking [62]. In contrast, destination-rich neighbourhoods visited by large crowds may be too noisy and chaotic for recreational walking. On the other

hand, places visited by a small number of people may be perceived as more interesting and attractive if they offer access to a variety of destinations. Finally, participants reporting higher levels of perceived sitting facilities showed a negative association between destination accessibility within a 20-minute walk from home and weekly minutes of within-neighbourhood walking for recreation among regular walkers. The high prevalence of sitting facilities in destination-rich neighbourhoods may be an indicator of highly popular commercial area that are too crowded and noisy to promote recreational walking.

The direction of the moderating effects of profiles of combined neighbourhood non-destination characteristics on the associations between destination accessibility and walking for recreation was also different to that originally hypothesised. A positive association between destination accessibility and within-neighbourhood non-zero weekly minutes of walking for recreation was only found in older adults with "poor perceptions" of their neighbourhood. Also, the association between destination accessibility within a 20-minute walk from home and the same walking outcome was negative for older adults with "good perceptions" of their neighbourhood. Again, it appears that destination-rich neighbourhoods can promote walking for recreation only if they do not offer other attractive streetscape characteristics, such as good pedestrian infrastructure, connectivity aesthetics and the presence of other people. In the presence of desirable non-destination characteristics, good access to destinations appears to be a deterrent to walking for recreation among Hong Kong older adults. This is understandable as Hong Kong is an ultra-dense city with very good access to services across most of the territory [43]. Thus, since walking for recreation is mainly undertaken along the street network in Hong Kong [244] older adults may prefer engaging in this activity in places that have fewer destinations and are less noisy as long as the streetscape is sufficiently attractive.

Study Strengths and Limitations

The main strength of this study is the examination of moderating effects of nine different perceived neighbourhood non-destination characteristics on associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and weekly frequency/minutes of walking for different purposes in older adults. The examination of moderating effects of profiles of the nine perceived neighbourhood non-destination characteristics is particularly novel. Only a handful of previous studies have attempted to examine perceived neighbourhood non-destination characteristics as moderators on destination-walking associations. However, those studies employed variable-centred analytical techniques such as regression modelling to investigate moderating effects of perceived neighbourhood non-destination on bivariate relationships between a specific destination and walking outcomes [53, 61, 62, 83]. Such methodology may not capture some moderating effects as different neighbourhood environments may exhibit unique spatial distributions of neighbourhood features.

Study limitations include the use of observational cross-sectional data which does not allow the assessment of causal relationships. Additionally, we were unable to adjust the analyses for participants' length of residence in their neighbourhood, which may influence their levels of familiarity with the neighbourhood environment and, hence, their responses [91, 154, 245, 246]. Potential confounders, such as car ownership, health status and neighbourhood self-selection were not included in the analyses [53, 62, 156]. Future research could address the above limitations and extend our findings to geographic contexts with different neighbourhood characteristics and populations for generalisability purposes. Furthermore, future studies could compare our findings with objectively-assessed neighbourhood measures for validation purposes and to better understand how perceptions of destination accessibility relate to objective measures of the same [90].

6.6 Conclusion

Our findings suggest that, in general, in an ultra-dense city such as Hong Kong where destinations are generally available in the great majority of neighbourhoods and older adults engage in large amounts of walking for different purposes, further increases in destinations accessibility may not necessarily lead to increases in the amount of walking. This is likely why our previous study did not find significant positive associations between destination accessibility and walking outcomes and the present study found only a few perceived neighbourhood non-destination characteristics that moderated the associations of destination-accessibility and walking in the expected direction. These non-destination attributes were sitting facilities in relation to walking for transport and safety from crime and presence of bridges/overpasses (connectivity) in relation to walking for recreation. To further increase the current levels of walking for transportation among Hong Kong older adults, improvements in destination accessibility would need to be accompanied by the installation of sitting facilities, while to increase the levels of walking for recreation, enhancements in destination accessibility would need to be accompanied by increases in perceived safety from crime and improvements in connectivity (provision of bridges/overpasses to avoid busy roads).

Although the direction of several moderating effects was opposite to that expected, they support the hypothesis that neighbourhood non-destination characteristics interact with destination accessibility to shape Hong Kong older adults' walking behaviours. For example, this study suggests that destination-rich and crowded areas may deter older adults from engaging in large amounts of walking for transport especially if they have to walk for more than 10 minutes to reach these destinations. Providing better access to destinations of daily living to increase walking for transport seems to be particularly important to older adults living in neighbourhoods with activity-unfriendly characteristics, such as high levels of traffic hazards, fewer people and poor pedestrian infrastructure. The same holds for walking for

recreation. Older adults living in neighbourhoods perceived to have many barriers to walking, a poor pedestrian infrastructure, traffic hazards and few people appear to be motivated to engage in walking for recreation if they have good access to destinations with a 20-minute walk from their homes. This study suggests that policymakers in Hong Kong and other ultra-dense metropolises should not only focus on optimising or improving the distance between destinations and residents' homes but also focus on improving other neighbourhood non-destination features such as crime safety, connectivity and availability of sitting facilities that may facilitate older adults' walking for different purposes.

6.7 Acknowledgements

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CHAPTER 7

GENERAL DISCUSSION

CHAPTER 7: GENERAL DISCUSSION

7.1 Introduction

The first two subsections of this chapter provide an in-depth summary of the aims and findings from the three empirical studies (Studies One (Chapter 4), Two (Chapter 5) and Three (Chapter 6)) in this PhD thesis. The next four subsections of the chapter discuss the strengths, limitations, policy implications and significance of the thesis. Recommendations for future research are then provided and followed by the overall conclusions.

7.2 Aims of the thesis

The overall objective of this thesis was to investigate and compare the relationships of perceived destination accessibility in the neighbourhood with walking for transport and recreation in older adults living in low- and high-density urban environments. To achieve this overall objective, data from two extant epidemiological studies conducted in a low-density city (Brisbane, Australia) and a high-density city (Hong Kong, China), and with comparable exposure and outcome measures, were used.

This thesis followed a PhD by Publication format. The overall thesis objective was divided into three principal aims. As indicated above, each principal aim of this PhD thesis was addressed by an empirical study with distinct rationales, aims and statistical methods.

Study One (Chapter 4), entitled "*Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China)"* addressed the first major aim of this thesis. This study had several sub-aims, with the principal aim being to characterise perceived destination accessibility of 12 types of destinations (*supermarket, café/restaurant, fruit and vegetable*

shop, fast food restaurant, public transport, public park, post office, library, primary school, childcare centre, chemist/drug store and doctor/medical centres) within a 5-, 10- and 20-minute walk from home in older adults residing in the two cities. The between-city differences in perceived access to specific destinations and mixes of destinations were then examined and used to explain large between-city differences in walking for different purposes.

Study Two (Chapter 5), entitled "*Associations between latent classes of perceived neighbourhood destination accessibility and walking behaviours in older adults of a low-density and a high-density city"* addressed the second major aim of this thesis. This study extended the findings from Study One by examining the associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and self-reported weekly minutes of overall (location non-specific) walking for transport and recreation in older adults residing in the two cities. Additionally, Study Two examined the associations between perceived destination accessibility within a 5-, 10- and 20-minute walk from home and self-report measures (weekly frequency and minutes) of within-neighbourhood walking for transport and recreation in older adults within the context of Hong Kong. To the best of my knowledge, this was the first study to examine destination-walking relationships in older adults using perceived destination accessibility types, rather than specific destinations, as the main exposure variable [53, 61].

Study Three (Chapter 6), entitled "*Moderating effect of perceived neighbourhood non-destination characteristics on the associations between perceived destination accessibility types and walking behaviour in Hong Kong Chinese older adults"* addressed the third and final principal aim of this thesis. This study extended the findings from Study One and Study

Two by examining the moderating effects of nine perceived neighbourhood non-destination characteristics (*physical barriers to walking; pedestrian infrastructure; aesthetics; the presence of people; traffic hazards; traffic speed; safety from crime; sitting facilities; and presence of bridges/overpass*) on the associations of perceived destination accessibility within a 5-, 10- and 20-minute walk from home with self-report measures of overall (location non-specific) and within-neighbourhood walking for transport and recreation in older adults within the context of Hong Kong. To the best of my knowledge, this was the first study to examine nine different neighbourhood attributes (perceived neighbourhood non-destination characteristics) as moderators of associations between perceived destination accessibility types and walking behaviour in older adults. Importantly, this was the first study to use profiles of neighbourhood non-destination attributes (a combination of nine perceived neighbourhood non-destination characteristics) as moderators of the destination-walking relationships in older adults.

The following section (7.3) outlines the key study-specific findings in detail and how they relate to findings from previous research.

7.3 Key findings of the thesis

Study One: The results from this study suggest that the older adults residing in the ultra-dense city, Hong Kong, perceived considerably higher levels of accessibility of a variety of destinations in their neighbourhoods across all walking distances from home compared to those residing in the low-density city, Brisbane. Between-city differences in perceived accessibility of specific destinations were larger for shorter distances (5-minute and 10-minute walk) than longer distances (20-minute walk) from home. Furthermore, the absolute

between-city differences in the percentage of older adults with perceived access to specific destinations were much larger for shorter distances than longer distances from home. Specific destination types that showed differences in perceived accessibility between the two cities and also varied across all the distance categories were *supermarket, café/restaurant, fruit & vegetable shop, fast food restaurant, primary school, childcare centre, chemist/drug store and doctor/medical centre*. Perceived access to those destination types has been shown to influence walking behaviours in older adults, especially walking for transport, across many studies [53, 61]. Perceived access to public parks did not significantly differ between the two cities across all the walking time categories. This suggests that the two cities may have similar levels of public park accessibility across their neighbourhoods. Moreover, the significance of between-city differences in the odds of perceived access to the *post office, library and public transport* varied across the walking time categories (i.e., distances).

In general, the latent structures of perceived access to the 12 destinations differed across all walking distance categories. Further, the percentage of older adults falling into neighbourhoods perceived to have good access to destinations was higher for destination accessibility measures based on larger distances from participants' homes.

The neighbourhoods in both cities could be classified into perceived destination accessibility types (latent classes) that were primarily reflective of the overall perceived level of access to the 12 destinations —"Good access", "Limited access" and "Poor access"— rather than perceived access to different mixes of destinations (e.g., "Good access to food outlets; limited access to recreational destinations", "Good access to schools and post office; limited access to parks"). A higher number of latent classes (e.g., destination accessibility types) were identified in Brisbane in comparison to Hong Kong, suggesting that there were higher levels

of heterogeneity in perceived destination accessibility within a 5- and 10-minute walk from home among older adults in Brisbane than among older adults in Hong Kong [247]. The fewer subgroups (i.e., two subgroups) identified across perceived destination accessibility within a 5- and 10-minute walk from home in Hong Kong as compared to Brisbane (three subgroups), and the large percentage of Hong Kong older adults falling in the 'good access' category of neighbourhoods, is an indication that Hong Kong residents may perceive equitable access to destinations across most of their neighbourhoods [247]. This may be related to Hong Kong being an ultra-dense city known globally for its equitable access to mixes of destinations and efficient transportation system [85, 134], which may explain the much higher level of walking among Hong Kong than Brisbane older adults observed in this study. The latent structures of perceived destination accessibility within a 20-minute walk from home were similar between the two cities. Finally, in Brisbane, but not Hong Kong, older adults residing in low-SES neighbourhoods perceived to have higher levels of destination accessibility than those living in high-SES neighbourhoods. The latter finding may be attributable to Hong Kong government urban planning and transportation policies supporting an equitable distribution of community facilities and services [180].

Study Two: This study found that older adults in Brisbane who perceived having better access to destinations were more likely to engage in walking for transport across all walking time categories than those with poor access. Additionally, the participants in Brisbane with good access to destinations within a 20-minute walk from home were more likely to engage in walking for recreation in their neighbourhoods compared to those who reported having poor access. As Brisbane is a low-density city with high levels of dependency on private vehicles [248], the findings indicate that optimising destination accessibility— i.e., increasing diversity of destinations and transit stops, as well as the reliability of transportation

systems— could help increase the levels of walking for transport and recreation in residents of low-density cities.

No significant associations between perceived destination accessibility and the likelihood of self-reported weekly minutes of location non-specific walking for transport and recreation were observed among Hong Kong older adults. As Hong Kong is an ultra-dense city with neighbourhoods that are typically destination-rich and have efficient transportation systems [85], this is not surprising. Residents are likely to have access to a variety of destinations within a short walking distance from home as well as an efficient transportation system to help combine both walking and public transport utilisation. A city with such neighbourhoods can facilitate the accumulation of high levels of walking in older adults [76, 96]. For example, in Study One, the results indicated that 88.2% of the sample (N=484) had good access to destinations within a 20-minute walk in Hong Kong as compared to a 68.3% of the sample (N=793) in Brisbane. The percentage of older adults with good access to destinations was consistently higher in Hong Kong than in Brisbane across all the walking distances, and this could be the reason for the non-significant associations between destination accessibility and walking observed among Hong Kong participants. The lack of significant associations of perceived destination accessibility and self-report measures of walking for different purposes in older adults within the context of Hong Kong may also be due to underlying factors that influence destination-walking associations in older adults, suggesting the need for further assessment. In fact, although perceived destination accessibility within walking distance from home alone can influence walking behaviours to a certain level, it may not ultimately address the complex interplay between person-environment relationships holistically. This is because there may be other neighbourhood-level characteristics that could moderate the associations

between destination accessibility and walking behaviours in older adults. This issue was examined in Study Three [53].

Study Three: The findings from this study suggest that some perceived neighbourhood non-destination characteristics could independently or conjointly moderate the associations of perceived destination accessibility within a 5-, 10- and 20-minute walk from home with self-report measures of overall (location non-specific) and within-neighbourhood walking for transport and recreation in older adults of an ultra-dense metropolis (Hong Kong). As indicated above, this study examined profiles of, as well as independent, perceived neighbourhood non-destination characteristics as moderators of the destination-walking associations. The majority of the significant moderating effects observed in this study were in the opposite directions to those expected. A substantially higher number of moderation effects of both profiles of and independent perceived neighbourhood non-destination characteristics were observed regarding recreational walking than walking for transport.

In general, none of the nine perceived neighbourhood non-destination attributes moderated the association of perceived destination accessibility within a 5- and 10-minute walk from home and walking for transport. Only a couple of independent neighbourhood attributes moderated the association of perceived destination accessibility within a 20-minute walk from home with both overall and within-neighbourhood walking for transport. While among older adults with above-average levels of perceived presence of people in the street higher destination accessibility was predictive of fewer weekly minutes of overall walking for transport, older adults with above-average levels of perceived physical barriers reported 27% more weekly minutes of within-neighbourhood walking for transport if they resided in neighbourhoods perceived to have good rather than limited access to destinations. The first

unexpected moderating effect may be peculiar to high-density urban environments where destination accessibility accompanied by high levels of crowdedness may act as a deterrent to walking for transportation in older adults experiencing mobility problems. The second moderating effect may be due to older adults' reduced levels of mobility which would result in them engaging in walking for transport in a neighbourhood with many physical barriers to walking only if they have a wide range of destinations within walking distance. In absence of such destinations, they may engage in utilitarian walking outside of their neighbourhood.

Perceived sitting facilities and perceived traffic hazards showed moderation effects in relation to self-reported weekly frequency of within-neighbourhood walking for transport. As expected, an above-average number of perceived sitting facilities was associated with 29% higher self-reported weekly frequency of within-neighbourhood walking for transport when participants perceived good access to destinations within a 5-minute walk from home. This indicates that the provision of sitting facilities in the neighbourhood may encourage walking for transportation in older adults living in destination-rich neighbourhoods. In contrast, the moderating effect of perceived traffic hazards on the association between destination accessibility and frequency of within-neighbourhood walking for transport was in the opposite direction to that expected. Specifically, older adults reporting below-average levels of perceived traffic hazards showed a negative association between frequency of within-neighbourhood walking for transport and destination accessibility within a 10-minute walk from home. I speculated that this might be due to commercial areas with low traffic hazards being an indication that they might not be attractive to customers. Finally, latent profiles consisting of nine perceived neighbourhood non-destination characteristics moderated only the association of perceived destination accessibility within a 20-minute walk from home with weekly minutes of location non-specific walking for transport. Only participants living

in a neighbourhood characterised by poor perceived non-destination characteristics accumulated 54% more weekly minutes of location non-specific walking for transport if they perceived their neighbourhood to have good access to destinations. As previously noted for a few single undesirable non-destination characteristics, older adults living in neighbourhoods with poor non-destination characteristics may engage in walking for transportation only if they have access to a wide range of destinations within walking distance from their homes.

In relation to walking for recreation, a considerable number of moderating effects on the destination-walking associations were observed. Safety from crime was a perceived neighbourhood non-destination attribute that independently showed a consistent moderating effect in the expected direction. For example, only older adults reporting above-average levels of perceived safety from crime reported 31% more weekly minutes of location non-specific walking if they perceived to have good destination accessibility within a 10-minute walk from home. Similarly, only older adults reporting above-average perceived safety from crime had 47% higher weekly frequency of within-neighbourhood walking for recreation when they perceived good access to destinations within a 5-minute walking from home. This suggests that perceived safety from crime is a neighbourhood non-destination attribute that may be necessary to promote older adults' walking for recreation. Other perceived neighbourhood non-destination characteristics—pedestrian infrastructure, traffic hazards, aesthetics, presence of people in the street and sitting facilities—showed moderation effects but in opposite directions to those expected. The same held true for the profile of perceived neighbourhood non-destination characteristics. For example, participants residing in neighbourhoods characterised by poor neighbourhood perceptions had weekly minutes of within-neighbourhood walking 78% and 87% higher if they perceived having good access, rather than poor and limited access, to destinations within a 10-minute and 20-minute walk

from home, respectively. These results indicate that, in ultra-dense cities, good access to destinations may be an incentive for walking for recreation only in the absence of other attractive neighbourhood features that have been found to be positively associated with walking for recreation, such as aesthetics, a good pedestrian infrastructure and the presence of other people [62].

7.4 Strengths of this thesis

This section provides details of the strengths of this PhD thesis. The overall strengths of this thesis have been divided into three sections. These include (1) Study design and conceptual framework; (2) Comparison of cities based on perceived destination accessibility; and (3) Methodological considerations.

7.4.1 Study design and conceptual framework

This PhD thesis used observational cross-sectional data from two extant epidemiological studies on environmental correlates of physical activity in older adults conducted in Brisbane, Australia [153] and Hong Kong, China [163] that used comparable exposure and outcome measures and sampling procedures. The two studies were based on the socio-ecological framework of health behaviour and used similar sampling strategies —that is, older adults nested within neighbourhood environments varying in environmental characteristics — that maximise the variability in exposures within the study sites [68, 70].

7.4.3 Comparison of cities based on perceived destination accessibility

This thesis investigated the destination-walking relationships in older adults between two international cities with distinctly different environmental features: a low-density city (Brisbane, Australia) and an ultra-dense city (Hong Kong, China). The distinctly different

built environment features between the cities were vital, as they helped to maximise environmental variability and examine the generalisability (similarity) of findings across diverse geographical locations. It was essential to explore the between-city differences of latent structure of perceived destination accessibility and how those structures can influence walking for transport and recreation in older adults for policy and research purposes. Such a comparative investigation of destination-walking associations between cities with distinct features can help understand context-specific destination accessibility and walking behaviours to help inform policies for suitable interventions [92].

7.4.4 Methodological considerations

This thesis considered a wide range of statistical methods to address the overall aims. Thus, the thesis first operationalised participants' perceived access to destinations in their neighbourhoods using three different levels of accessibility —perceived destination accessibility within a 5-, 10- and 20-minute walk from home—suitable for measuring destination-walking associations in older adults. Since different types of neighbourhood destinations may have a synergistic effect on walking, examining the potential effects of access to destinations on walking behaviour using bivariate associations between single destinations and walking may provide a simplistic picture. Such investigation requires a more holistic approach that combines a variety of analytical methods, including person-centred and variable-centred techniques, which is a novel methodological approach employed to investigate the aims of this PhD thesis.

This thesis employed a person-centred technique (LCA) to first characterise perceived destination accessibility within a 5-, 10- and 20-minute walk from home (perceived destination accessibility types) as the primary exposure and then assess the associations

between perceived destination accessibility types and walking for different purposes in older adults. The person-centred technique considers the study observations (older adults) as the units of analyses to identify unobserved subgroups of older adults based on perceived destination accessibility. Such a novel methodology can help handle the interrelationship between individuals and their neighbourhood environment. It can also minimise measurement errors from the participants' responses [188]. This section on methodological considerations has been divided into four subsections, including (1) the exposure variable—latent classes of perceived destination accessibility; (2) the use of a variety of outcome variables within different contexts; (3) data analytical techniques—combination of person-centred and variable-centred approaches—to investigate study-specific aims; and (4) the moderation analysis of other neighbourhood non-destination characteristics on the associations between perceived destinations and walking for different purposes in older adults within the context of Hong Kong.

7.4.4.1 Exposure variable—latent classes of perceived destination accessibility

This PhD research program operationalised perceived destination accessibility within a 5-, 10- and 20-minute walk from home and derived latent classes based on perceived destination accessibility across distance categories. The latent classes—subgroups of older adults comprising a combination of perceived destination accessibility—were the main exposure variables in the analyses. As noted earlier, these types of variables have the advantage of being able to identify higher-order interactions of destination types. Additionally, the examinations of associations of walking behaviours with latent classes of perceived destination accessibility within a 5-, 10- and 20-minute walk from home, rather than with the conventional 20-minute walk from home based on healthy adults [96], can help operationalise appropriate destination accessibility measures in older adults.

7.4.4.2 The outcome variables – walking for various purposes within different contexts

This PhD thesis used weekly minutes of location non-specific walking for transport and recreation as the primary outcome variable in the comparative assessment between the two cities in Study One and Study Two. Additionally, the thesis used weekly frequency/minutes of within-neighbourhood walking for transport and recreation together with location non-specific measures as outcome variables in Study Three (only among Hong Kong participants). Investigating associations between the latent classes of perceived destination accessibility and frequency/minutes of walking for different purposes in different contexts can help inform local and international policies and interventions that have the potential to increase walking behaviours. Such evaluation has been called for [53, 61, 62, 92].

7.4.4.3 Data analytical techniques to investigate study-specific aims: Combination of a person-centred approach and a variable-centred approach

This PhD research program contributes to the existing knowledge in the field by employing both person- and variable-centred analytical methods to address all the major aims. The use of a person-centred analytical approach, notably, the LCA to identify subgroups of older adults in the two cities based on perceived neighbourhood destinations within a 5-, 10- and 20-minute walk from home was the backbone of this program of research. LCA is based on a statistical measurement model that posits that there are more than one unobserved (latent) subgroups of participants (i.e., in this thesis, represented by the latent structure of perceived destination accessibility) within the study population that could be inferred from the observed indicators (represented by the questionnaire items) [192, 196, 249]. For population-based prevention and intervention strategies, the identification of high-risk subgroups can help inform population-based interventions that are suitable and cost-effective. Individuals experience more than one attribute in their neighbourhood so that identifying subgroups of

participants comprising a combination of contextual factors, rather than bivariate relationships between a specific type of destination and walking, may provide higher statistical power to capture potential environmental influences [188, 204]. Adjustment for the hierarchical data structure in the data analyses is also another strength of this research.

7.4.4.4 Perceived features of the neighbourhood environment as moderators of destination accessibility-walking associations

Investigating nine different perceived neighbourhood non-destination characteristics as potential moderators of associations between the latent classes of perceived destination accessibility across different distance categories and walking behaviours within a Hong Kong context is another major strength of this PhD research program. These non-destination characteristics included *physical barriers to walking, pedestrian infrastructure, aesthetics, the presence of people, traffic hazards, traffic speed, safety from crime, sitting facilities and the presence of bridges/overpass*. Such an investigation is novel as existing research has predominantly focused on individual-level characteristics, including age, education and sex as potential moderators of destination-walking associations [53, 61, 62]. Despite the increasing number of studies in the field of destination-walking relationships, only a handful of studies have attempted to consider neighbourhood attributes, such as safety from crime and traffic, pedestrian infrastructure and aesthetics as moderators of neighbourhood-walking relationships [53, 61, 62, 183]. However, those studies employed variable-centred approaches, such as regression to assess bivariate relationships between specific environmental attributes and specific walking behaviours. From a socio-ecological perspective, individuals' walking behaviours are influenced by multiple levels of interacting physical (built) and social environmental factors [68, 70]. Investigating bivariate relationships between factor-outcome variables may miss the synergistic effect that exists as a result of the

operation of multiple interacting environmental factors. The methodology—combination of both person-centred and variable-centred approaches—used to investigate the aims of this PhD thesis has the power to capture the multilevel interplay between environmental factors.

7.5 Limitations of this thesis

This section addresses the overall limitations of the thesis. Although this PhD research program used a novel approach to investigate the research aims, there were several limitations which need to be considered in future research.

7.5.1 Causal inference assessment

This PhD thesis used cross-sectional data for the three empirical studies. Observational cross-sectional data can only provide insights into associations between aspects of the environmental context (perceptions of neighbourhood environment) and older adults' self-report measures of walking for transport and recreation. Causal inference cannot be drawn from the observed findings. As neighbourhood environments are not static but evolve over time as a result of land-use and transportation policies [245], future research should consider examining how structural changes in the neighbourhood environment influence older adults' walking for different purposes over time.

7.5.2 Participants' length of residence in the neighbourhood and neighbourhood self-selection (misclassification bias)

This thesis did not adjust for participants' length of residence in their neighbourhood and neighbourhood self-selection (i.e., participants living in a neighbourhood with good destination accessibility because they enjoy walking) in the analyses due to lack of such data. Participants' length of stay in their neighbourhood environment could influence their levels

of familiarity, their spatial knowledge of the neighbourhood environment and their responses [91, 245, 246]. Incorrect responses can contribute to misclassification bias (e.g., incorrect classification of participants' responses into latent classes of perceived destination accessibility), which could influence the associations [245]. Controlling for neighbourhood self-selection may in part address the problem of reverse causality [53]. Future research should assess participants' length of residence in their neighbourhood and neighbourhood self-selection to control for their potential confounding effects in the analyses.

7.5.3 Lack of comparable data across study sites

This thesis was unable to compare part of the findings in Study Two and the entire findings in Study Three between the two cities. While the Hong Kong Elderly study had all the information on older adults' self-report measures of within-neighbourhood walking for transport and recreation and moderators (perceived neighbourhood non-destination characteristics), the HABITAT study lacked this information, which prevented thorough comparative investigations between the two cities. Future multi-site studies could consider collecting this information for generalisability purposes.

7.6 Significance of the thesis

This PhD thesis has contributed to the existing knowledge and public health research by conceptualising destination accessibility in a novel way and by providing information on profiles of perceived destination accessibility within a 5-, 10- and 20-minute walk from home related to walking behaviour in older adults from two cities with very different built environmental features. The different findings observed in the low- and high-density urban contexts highlight the importance of collecting local environmental exposure and behavioural data to inform local urban planning, transportation and public health policies.

Further, the operationalisation of older adults' perceived destination accessibility using perceived distances defined as a 5-, 10- and 20-minute walk from home can help assess the relative walking distance suitable for environmental interventions aimed to improve walking behaviours in older adults. This is because information on the associations between the here-adopted measures of destination accessibility and walking for different purposes can help determine the level of destination accessibility (defined as time needed to walk to/from destinations) having the strongest impact of older adults' walking behaviours. This type of approach is more informative and appropriate than using the conventional 20-minute walk from home definition of accessibility derived from general adult populations [96].

As older residents may have different destination accessibility experiences and preferences of neighbourhood characteristics, it is necessary to identify subgroups of residents within a heterogeneous population that present specific patterns of accessibility and accessibility-walking associations [96, 250]. The methodology employed in this thesis can be utilised to identify vulnerable subgroups of older adults that require specific types of interventions (e.g., provision of a specific mix of destinations within a 5-minute rather than 10-minute walk from home). The approach used in this thesis can also help identify other neighbourhood non-destination characteristics that may be necessary to optimise the effects of perceived destination accessibility on walking for different purposes in older adults. Further, the findings from this thesis suggest that optimising destination accessibility, creating safe and convenient neighbourhood environments for older adults, can help promote neighbourhood walking behaviours. However, the types, focus and scale of interventions required to promote walking depend on the local urban context (e.g., on the level of urban density of a city).

Accessing local destinations by foot does not only increase levels of PA, but can also promote local business and economic activities, and increases social interactions through incidental contacts. When people walk in their neighbourhood, there is a higher likelihood that they will meet their neighbours, which has the propensity to increase neighbourhood interactions. This can help increase participation in neighbourhood activities and thus, lower social isolation [4, 146]. Further, the optimisation of destination accessibility within walking distance from home and the improvement of other neighbourhood-level non-destination characteristics may encourage non-motorised travel activities in neighbourhood environments. Higher levels of non-motorised travel may have the potential to lower traffic congestion. This can reduce gas emission noise from private vehicles which, in turn, can help improve air quality and lower noise pollution.

7.7 Policy implications of the thesis

Evidence suggests that there is a high prevalence of low levels of PA in older adults, with associated adverse effects, including cognitive impairment, cardiovascular diseases, some cancers and type II diabetes [4, 75]. This implies that the expected increase in the older adult population may place a tremendous challenge on public health, health care, and social and economic activities worldwide [4]. Additionally, there is evidence that perceptions of the neighbourhood environment based on destination accessibility, crime and traffic safety, aesthetics, nature and pedestrian infrastructures play a crucial role on older adults' PA behaviour—mainly walking behaviours [53]. The findings from this thesis suggest that creating a safe neighbourhood environment with mixes of destinations within walking distance from home can help promote walking behaviours in older adults [146]. A healthy and safe neighbourhood environment may help encourage an active lifestyle for improving wellbeing and quality of life in older people [4].

Identifying high-risk subgroups of older adults within heterogeneous populations may help inform policies as to what type of intervention is required to address a specific challenge in these high-risk subgroups [96]. The approach used in this thesis can help assist policymakers, future research and practitioners to identify a more appropriate and holistic way of assessing older adults' perceptions of their neighbourhood environment. For example, an examination of differences in walking behaviours between subgroups of residents with different profiles of perceived environmental characteristics can help uncover the structural and multidimensional influences—synergistic effect—of neighbourhood environmental characteristics on individuals' activity patterns [53, 75]. Such a methodology aligns with the Transportation Research Board's recommendation on the associations between environmental context and residents' PA behaviour [96].

7.8 Recommendations for future research

Neighbourhood environments are not static but complex and dynamic, comprising of a combination of several characteristics operating together across multiple levels to shape individuals' PA behaviour, such as walking for different purposes and health outcomes over time [68, 70, 75]. The complex and dynamic nature of neighbourhood environments can place a challenge on person-environment relationships research and such relationships require a holistic framework to address them. This suggests that environmental and public health policies and interventions should not only focus on improving single environmental attributes but should consider targeting unique subgroups of older residents with particular perceptions of the environment. This is because two individuals may have different experiences in the same neighbourhood environment based on how they react to the characteristics of the neighbourhood environment. That is, one neighbourhood environmental attribute may be essential for one group but irrelevant for another group. In line with this, it has been

recommended that future research employs a more holistic analytical approach incorporating a mix of person-centred and variable-centred methodologies rather than the traditional bivariate approach [53, 75].

Evidence suggests that the associations among neighbourhood environment characteristics and PA likely vary by subgroups of people and geographical contexts. Therefore, to develop cost-effective population-based interventions, it is necessary to identify various subgroups of high-risk individuals needing specific interventions [96]. Future research could employ several measures, including both objective and perceived measures, to examine person-environment associations over time. Future studies could focus on applying a latent transitional analysis (longitudinal extension of latent class analysis) to investigate the associations of structural trends or patterns of neighbourhood environment with PA in older adults over time [188, 245]. Moreover, future studies could replicate the methodologies in this thesis to conduct a comparative investigation in different cities for generalisability purposes.

7.9 Overall conclusion

Given the estimated increasing trend in the global ageing population and the numerous health challenges associated with the ageing process as a result of the decline in levels of PA, providing neighbourhood environments that can promote walking for different purposes may promote active and healthy ageing. This is because older adults are more likely to spend the majority of their time in their neighbourhoods and the perceptions of their neighbourhood environments can facilitate or inhibit their walking for transport and recreation. This PhD thesis suggests that providing neighbourhoods with higher levels of destination accessibility can help encourage walking for different purposes, especially walking for transport in older

adults. However, other perceived neighbourhood non-destination characteristics such as safety from crime, sitting facilities, pedestrian infrastructures, connectivity, aesthetics and the presence of people in the street can moderate destination-walking associations. This PhD thesis has addressed methodological issues associated with the complex interplay of the neighbourhood environment and walking behaviours in older adults using a more holistic analytical approach. Findings from this thesis can inform policymakers and stakeholders about the importance of providing safe, accessible neighbourhood environments with age-friendly amenities to help increase levels of PA in older adults in different geographical contexts.

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APPENDICES

APPENDICES

Appendix 1: Research Portfolio

List of Publications (Peer reviewed journal articles)

1. **Boakye-Dankwa, E.**, Nathan, A., Barnett, A., Busija, L., Lee, R. S., Pachana, N.,Turrell, G., Cerin, E. (2019). Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China). *Cities, 84*, 23-33. Doi: https://doi.org/10.1016/j.cities.2018.07.002

2. **Boakye-Dankwa, E.**, Barnett, A., Pachana, N. A., Turrell, G., & Cerin, E. (2019). Associations Between Latent Classes of Perceived Neighborhood Destination Accessibility and Walking Behaviors in Older Adults of a Low-Density and a High-Density City. *Journal of Aging & Physical Activity, 27*(4), 553-564. DOI: https://doi.org/10.1123/japa.2018-0297

Manuscript prepared for submission

1. **Boakye-Dankwa, E**., Barnett, A., Cerin, E., "Moderating effect of perceived neighbourhood non-destination characteristics on the associations between perceived destination accessibility types and walking behaviour in Hong Kong Chinese older adults."

Presentations

1. **Oral presentation at Urban Transitions 2018 conference**, 25-27 November 2018, Sitges, Barcelona Spain. "Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China)." (**Boakye-Dankwa, E.**, Barnett, A., Busija, L., Lee, R. S., Pachana, N., Turrell, G., Cerin, E.).

2. **Three Minute Thesis (3MT)** competition, ACU, Melbourne heat, July 2018.

Appendix 2. Declaration of Authorship

Appendix 2.1 Published Manuscript: Study One (Chapter 4)

Boakye-Dankwa, E., Nathan, A., Barnett, A., Busija, L., Lee, R. S., Pachana, N., Turrell, G., Cerin, E. (2019). Walking behaviour and patterns of perceived access to neighbourhood destinations in older adults from a low-density (Brisbane, Australia) and an ultra-dense city (Hong Kong, China). *Cities, 84*, 23-33. Doi: https://doi.org/10.1016/j.cities.2018.07.002

Authors' Statement

Ernest Boakye-Dankwa (PhD Candidate)

As a PhD candidate, I acknowledge that my contribution to the above study was 50%. I conducted the literature review, data management, data analyses and interpreted the results. Additionally, I drafted the manuscript for feedback and prepared the final version for publication.

Signature: Date: 21/11/2019

Dr Andrea Nathan (Former Assistant Supervisor)

Dr Nathan assisted with the design of the analysis, provided feedback to help revise the manuscript for publication. I acknowledge that Dr Nathan's contribution to the above study was 7%.

Signature: _____ Date: 22/11/2019

Associate Professor Anthony Barnett (Co-supervisor)

A/Prof Barnett contributed to the design of the analytical framework, provided critical feedback to help revise the manuscript for publication. I acknowledge that A/Prof Barnett's contribution to the above study was 10%

Signature: Date: 22/11/2019

Dr Lucy Busija (Former Assistant Supervisor)

Dr Busija contributed to the analytical data plan and provided feedback on the interpretation of results. I acknowledge that Dr Busija's contribution to the above study was 5%.

Signature: Date: 25/11/2019

Dr Ruby. S. Lee

Dr Lee contributed to facilitating the Hong Kong Elderly study and provided feedback on the manuscript. I acknowledge that Dr Lee's contribution to the above study was 2%.

Signature  Date: 25/11/2019

Professor Nancy A. Pachana

Professor Pachana contributed to the design of the HABITAT study and agreed on using the HABITAT data sets for this PhD research program. In addition, Professor Pachana commented on the manuscript for publication. I acknowledge that Professor Pachana's contribution to the above study was 3%.

Signature: Date: 24/11/2019

Professor Gavin Turrell

Professor Turrell contributed to the design of the HABITAT study and provided access to the HABITAT data set for this thesis. Additionally, Professor Turrell provided feedback on the manuscript for publication. I acknowledge that Professor Turrell's contribution to the above study was 3%.

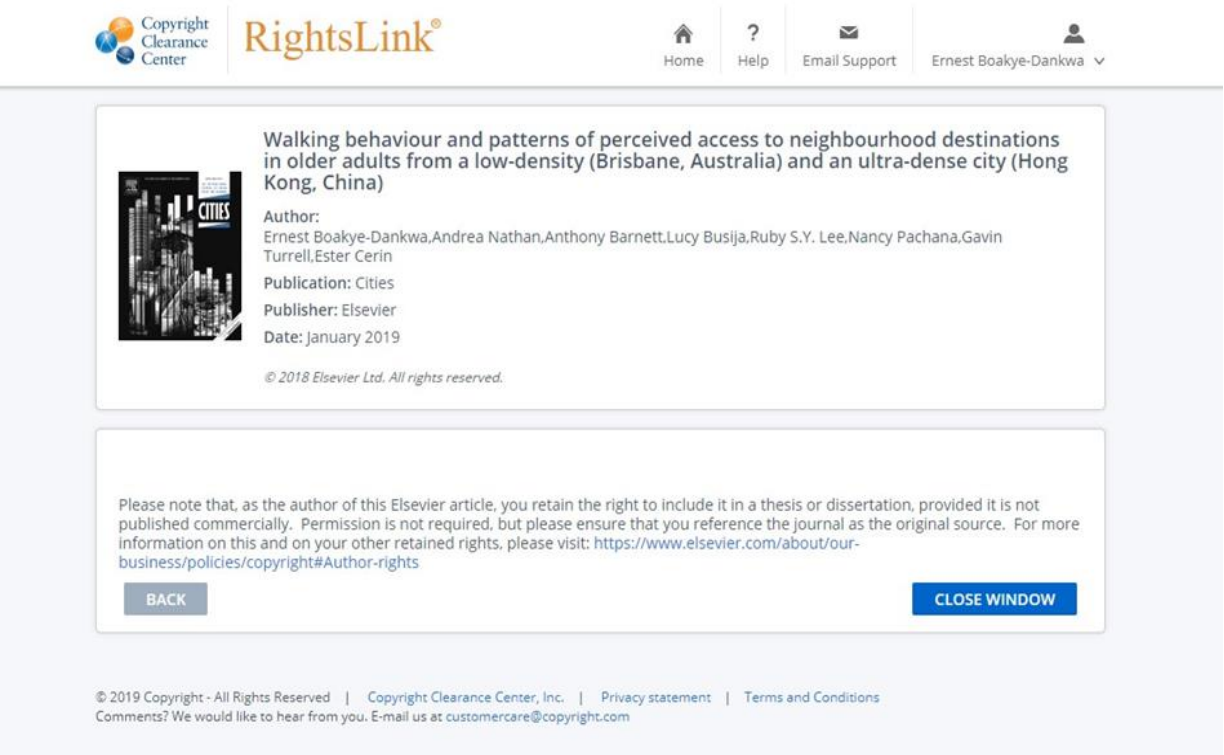
Signature: Date: 25/11/2019

Professor Ester Cerin (Principal Supervisor)

Professor Cerin designed the Hong Kong Elderly study and provided funding for this PhD research. Additionally, Professor Cerin contributed to the analytical framework, provided support on data analyses, results interpretation, and feedback on the manuscript for publication. I acknowledge that Professor Cerin's contribution to Study One was 20%.

Signature: Date: 22 November 2019

Appendix 2.1.1 Copyright permission from Cities to use the whole Study One in the thesis



Appendix 2.2 Published Manuscript: Study Two (Chapter 5)

Boakye-Dankwa, E., Barnett, A., Pachana, N. A., Turrell, G., & Cerin, E. (2019). Associations Between Latent Classes of Perceived Neighborhood Destination Accessibility and Walking Behaviors in Older Adults of a Low-Density and a High-Density City. *Journal of Aging & Physical Activity*, *27*(4), 553-564. DOI: https://doi.org/10.1123/japa.2018-0297

Authors' Statement

Ernest Boakye-Dankwa (PhD Candidate)

As a PhD candidate, I acknowledge that my contribution to the above study was 55%. I conducted the literature review, data analyses and interpreted the results. Additionally, I drafted the manuscript for feedback and prepared the final version for publication.

Signature: Date: 21/11/2019

Associate Professor Anthony Barnett (Co-supervisor)

A/Prof Barnett contributed to the design of the analytical framework, provided critical feedback to help revise the manuscript for publication. I acknowledge that A/Prof Barnett's contribution to the above study was 15%.

Signature: Date: 22/11/2019

Professor Nancy A. Pachana

Professor Pachana contributed to the design of the HABITAT study and agreed on using the HABITAT data sets for this PhD research program. In addition, Professor Pachana commented on the manuscript for publication. I acknowledge that Professor Pachana's contribution to the above study was 4%.

Signature: Date: 24/11/2019

Professor Gavin Turrell

Professor Turrell contributed to the design of the HABITAT study and provided access to use the HABITAT data set for this thesis. Additionally, Professor Turrell provided feedback on the manuscript for publication. I acknowledge that Professor Turrell's contribution to the above study was 4%.

Signature: Date: 25/11/2019

Professor Ester Cerin (Principal Supervisor)

Professor Cerin designed the Hong Kong Elderly study and provided funding for this PhD research. Additionally, Professor Cerin contributed to the analytical framework, provided support on data analyses, results interpretation, and feedback on the manuscript for publication. I acknowledge that Professor Cerin's contribution to Study Two was 22%.

Signature: Date: 22 November 2019

Appendix 1.2.1: Copyright permission from the Journal of Aging and Physical Activity to Study Two

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Appendix 1.3 Manuscripts under preparation: Study Three (Chapter 6)

Boakye-Dankwa, E., Barnett, A., Cerin, E., "*Moderating effect of perceived neighbourhood non-destination characteristics on the associations between perceived destination accessibility types and walking behaviour in Hong Kong Chinese older adults*"

Authors' Statement

Ernest Boakye-Dankwa (PhD Candidate)

As a PhD candidate, I acknowledge that my contribution to the above study was 60%. I conducted the literature review, data management, data analyses and interpreted the results. Additionally, I drafted the manuscript for feedback and prepared the final version for publication.

Signature: Date: 21/11/2019

Associate Professor Anthony Barnett (Co-supervisor)

A/Prof Barnett contributed to the design of the analytical framework, provided critical feedback to help revise the manuscript for publication. I acknowledge that A/Prof Barnett's contribution to the above study was 15%.

Signature: Date: 22/11/2019

Professor Ester Cerin (Principal Supervisor)

Professor Cerin designed the Hong Kong Elderly study and provided funding for this PhD research. Additionally, Professor Cerin contributed to the analytical framework, provided support on data analyses, results interpretation, and feedback on the manuscript for publication. I acknowledge that Professor Cerin's contribution to Study One was 25%.

Signature: Date: 22 November 2019

Appendix 2: Supplementary data to Study One

Table 2A: Item-response probabilities for perceived destination types within a given walking time from participants' home

	Brisbane (n = 793)			**Hong Kong (n = 484)**	
	Perceived access within a 5-minute walk from home				
	Good Access 7.3% (n=58)	Limited Access 13.5% (n=107)	Poor Access 79.2% (n=628)	Good Access 50.2% (n=243)	Poor Access 49.8% (n=241)
Supermarket	0.961	0.270	0.000*	0.876	0.195
Café/Restaurant	0.925	0.445	0.015	0.890	0.160
Fruit &Vegetable Shop	0.822	0.212	0.000*	0.662	0.087
Fast Food Restaurant	0.860	0.366	0.003	0.691	0.087
Public Transport	0.974	0.909	0.473	0.845	0.376
Public Park	0.674	0.592	0.454	0.677	0.346
Post Office	0.804	0.171	0.006	0.388	0.065
Library	0.229	0.024	0.003	0.161	0.045
Primary School	0.378	0.285	0.146	0.618	0.248
Childcare Centre	0.445	0.332	0.069	0.693	0.285
Chemist/Drug Store	0.902	0.297	0.004	0.876	0.108
Doctor/Medical Centre	0.801	0.352	0.016	0.744	0.109
	Perceived destinations within 10-minute walk from home				
	Good Access 25.5% (n=202)	Limited Access 26.6% (n=211)	Poor Access 47.9% (n=380)	Good Access 79.3% (n=384)	Poor Access 20.7% (n=100)
Supermarket	0.980	0.317	0.003	0.972	0.512
Café/Restaurant	0.925	0.543	0.029	0.986	0.457
Fruit &Vegetable Shop	0.935	0.353	0.006	0.872	0.235

Fast Food Restaurant	0.843	0.404	0.008	0.882	0.188
Public Transport	0.995	0.972	0.770	0.975	0.645
Public Park	0.849	0.814	0.700	0.804	0.456
Post Office	0.855	0.320	0.020	0.649	0.043
Library	0.405	0.053	0.002	0.315	0.163
Primary School	0.615	0.502	0.289	0.838	0.286
Childcare Centre	0.598	0.440	0.136	0.818	0.291
Chemist/Drug Store	0.977	0.449	0.012	0.937	0.387
Doctor/Medical Centre	0.847	0.497	0.017	0.896	0.292

	Perceived destination within a 20-minute walk from home			
	Good Access 68.3% (n=542)	Poor Access 31.7% (n=251)	Good Access 88.2% (n=427)	Limited Access 11.8% (n=57)
Supermarket	0.928	0.091	1.000*	0.886
Café/Restaurant	0.933	0.255	0.992	0.875
Fruit &Vegetable Shop	0.910	0.159	0.993	0.515
Fast Food Restaurant	0.839	0.148	0.970	0.460
Public Transport	0.995	0.901	0.995	0.951
Public Park	0.949	0.808	0.937	0.720
Post Office	0.861	0.147	0.889	0.166
Library	0.467	0.014	0.556	0.293
Primary School	0.797	0.536	0.931	0.434
Childcare Centre	0.680	0.291	0.901	0.477
Chemist/Drug Store	0.969	0.194	0.988	0.709
Doctor/Medical Centre	0.893	0.202	0.973	0.712

*: Parameter estimate reached boundary value of 0 or 1.

Appendix 3: Ethical Approval (ACU Application ID: 2017-248N)

Appendix 3.1: The Hong Kong Elderly Study

THE UNIVERSITY OF HONG KONG

香 港  大 學

February 28, 2006

Dr. E. Cerin
Institute of Human Performance

Dear Dr. Cerin,

Reference No. EA120206: Application for Ethical Approval

I refer to your application for ethical approval of your project entitled "Development and validation of measures to study the effects of the built environment on walking in Hong Kong senior residents".

I am pleased to inform you that the application has been approved by the Human Research Ethics Committee for Non-Clinical Faculties regarding the ethical aspect of the above-mentioned research project.

Yours sincerely,

Terry K. Au
Chairman
Human Research Ethics Committee for Non-Clinical Faculties

THE REGISTRY 教 務 處
POKFULAM ROAD, HONG KONG. TEL:(852)2859 2111 FAX:(852)2858 2549
Printed on environmentally friendly paper

Appendix 3.2: The HABITAT Study

Data Access Expression of Interest Form

Instructions for completing this form are provided in the HABITAT Data Access Policy & Procedures

1. Lead Applicant (name, institution & email)

Ester Cerin, Institute for Health and Ageing, ACU; Ester.Cerin@acu.edu.au
Primary Supervisor of PhD candidate Ernest Boakye-Dankwa; ernest.boakyedankwa@myacu.edu.au

[this application is for data access related to Mr. Boakye-Dankwa's PhD program]

2. Purpose for Data Access Request

- [ ] Secondary analysis & publication
- [ ] Funding application
- [x] Student research project

3. HABITAT Chief Investigators part of initial discussions

- [x] Gavin Turrell
- [ ] Nicola Burton
- [ ] Wendy Brown
- [ ] Billie Giles-Corti
- [ ] Adrian Barnett
- [ ] Nancy Pachana

4. Other Collaborators (names & institutions)

Dr Lucy Busija (Institute for Health and Ageing, ACU) – Assistant Supervisor of Mr. Boakye-Dankwa Dr Andrea Nathan (Institute for Health and Ageing, ACU) – Assistant Supervisor of Mr. Boakye-Dankwa

Dr Anthony Barnett (Institute for Health and Ageing, ACU) – Co-supervisor of Mr. Boakye-Dankwa

All HABITAT Chief Investigators interested in the proposed project would be collaborators.

5. Brief Outline of Proposed Research

Version 9 (updated 15 July 2016)

HABITAT Project Manager to complete

Date EOI Received: 27/02/2017 Reference Number: 2017-04-EOI
te Notified: 2/03/2017 Outcome: Approved

a)Primary research question

The aims of the proposed project are:

1. To identifying types and profiles of neighbourhood destinations that are associated with higher levels of recreational and transportation physical activity in older community-dwellers (60+ year of age).

2. To examine the moderating effects of socio-demographic factors (gender, employment situation and motor vehicle ownership) and neighbourhood environmental factors (perceived aesthetics, pedestrian infrastructure, traffic safety and safety from crime) on the associations of destinations types and profiles with recreational and transportation physical activity.

b)Key variables (independent and dependent)

Independent: Walk time to nearest business or facilities (from ANEWS)

Dependent: Recreational physical activity; days last month walked to places; modes of transport

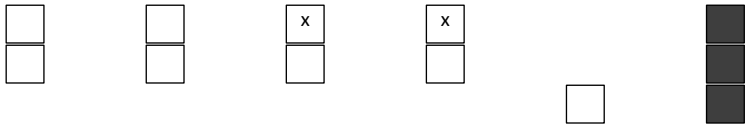
Moderators: Gender, employment situation, items from ANEWS: neighbourhood traffic,

surroundings, streets and footpaths, motor vehicle available

Covariates: apart from basic socio-demographics, reasons for moving to current address

c)HABITAT data sources

	2007	2009	2011	2013	2014	2016
Mail Survey						
Geospatial & Linked Data						
Clinical Substudy Assessments						



d)Participant subgroups of interest

Participants aged 60+ years in 2011.

e)Does the request involve additional data collection and/or record linkage?

[x] No
[ ] Yes (briefly describe using plain language)

6. I have read the *HABITAT Study Data Access Policy & Procedures* and the *HABITAT Study Confidentiality & Data Use Agreement* and agree to abide by its conditions

[x] Yes

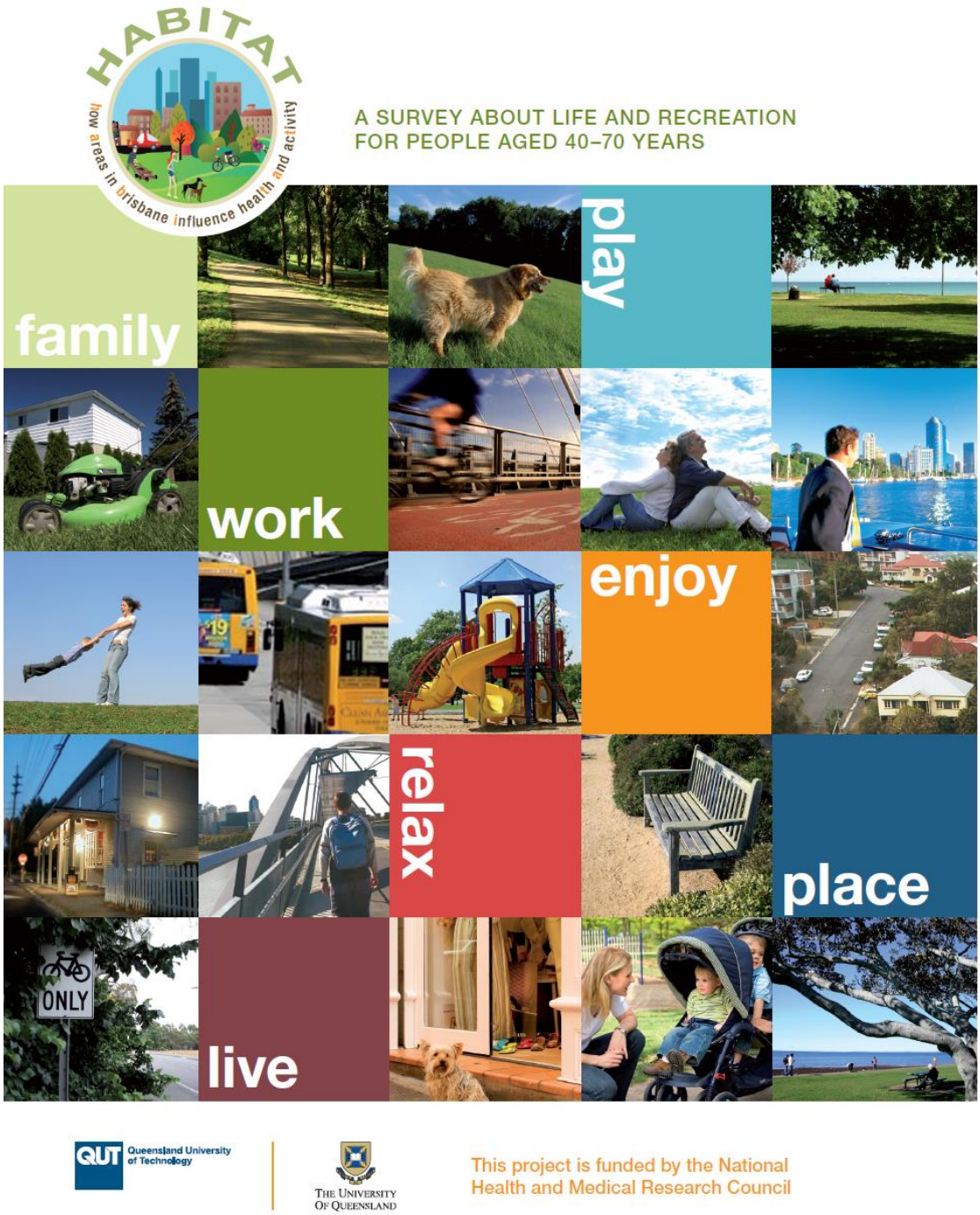
[ ] No

Submit completed form to HABITAT Research Officer (aislinn.healy@acu.edu.au) and refer to table for likely outcome notification timelines in 2017

EOIs received by COB	Outcome notification
11 February	Late February
10 March	Late March
14 April	Late April
12 May	Late May
16 June	Late June
14 July	Late July
11 August	Late August
15 September	Late September
13 October	Late October
17 November	Late November

Apendix 4: Survey Information

Appendix 4.1 HABITAT SURVEY



QUT Queensland University of Technology
The University Of Queensland
This project is funded by the National Health and Medical Research Council

We greatly appreciate your help with this survey.
Your answers are very important to us.

Please remember:

- Your answers will be treated as strictly **PRIVATE AND CONFIDENTIAL**
- There are no right or wrong answers: we just want to know what YOU think.
- The person doing the survey MUST be the person to whom it is addressed
- Some of the questions may sound the same. However, it will help us greatly if you answer all questions.

If you have any questions:
Please call our Freecall number on 1800 452 543.

Once you have completed the survey, please return it in the enclosed reply paid envelope (no stamps necessary).

1.8 About how long would it take you to **WALK** from your home to the **NEAREST** business or facility listed below? **(Please think of the closest one)**

Please tick one box for each item.	1–5 minutes	6–10 minutes	11–20 minutes	21–30 minutes	More than 30 minutes	Don't know
Supermarket	☐	☐	☐	☐	☐	☐
Fruit and vegetable shop	☐	☐	☐	☐	☐	☐
Bike path	☐	☐	☐	☐	☐	☐
Post office	☐	☐	☐	☐	☐	☐
Library	☐	☐	☐	☐	☐	☐
Primary school	☐	☐	☐	☐	☐	☐
High school	☐	☐	☐	☐	☐	☐
Café/restaurant	☐	☐	☐	☐	☐	☐
Fast food restaurant	☐	☐	☐	☐	☐	☐
Chemist	☐	☐	☐	☐	☐	☐
Bus stop	☐	☐	☐	☐	☐	☐
Train station	☐	☐	☐	☐	☐	☐
Public park	☐	☐	☐	☐	☐	☐
Liquor store/bottle shop	☐	☐	☐	☐	☐	☐
Doctor/medical centre	☐	☐	☐	☐	☐	☐
Ferry terminal	☐	☐	☐	☐	☐	☐
Childcare centre	☐	☐	☐	☐	☐	☐
Post box	☐	☐	☐	☐	☐	☐
Oval or sports field	☐	☐	☐	☐	☐	☐
Pub, hotel or tavern	☐	☐	☐	☐	☐	☐

1.9 What type of residence do you currently live in?

Please tick one.

Separate house	☐	Flat or unit in block of 2 or 3 storeys	☐
Semi-detached house or duplex	☐	Flat or unit in block of 4 or more storeys	☐
Townhouse or terrace	☐	House or flat attached to office, shop, etc.	☐
Single storey flat or home unit	☐	Other *(please specify)*	

Appendix 4.2: Hong Kong Elderly Study Questionnaire

We would like to find out about the way that you perceive or think about your neighborhood. Please answer the following questions about your neighborhood and yourself.

A. Types of residences in your neighborhood

Please choose the answer that best applies to you and your neighborhood.

1. How common are <u>detached single-family residences</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

2. How common are <u>multi-family houses or apartments or condos of 1-3 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

3. How common are <u>apartments or condos of 4-6 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

4. How common are <u>apartments or condos of 7-12 stories</u> in your immediate neighborhood?

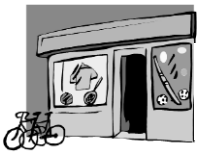
1	2	3	4	5
None	A few	Some	Most	All

5. How common are <u>apartments or condos of 13-20 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

6. How common are <u>apartments or condos of more than 20 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All



B. Stores, facilities, and other things in your neighborhood

About how long would it take to get from your home to the <u>nearest</u> businesses or facilities listed below if you <u>walked</u> to them? Please put only <u>one</u> check mark (√) for each business or facility.

	1-5 min	6-10 min	11-20 min	20-30 min	30+ min	don't know
example: gas station	1. ___	2. ____	3. √	4. ____	5. ____	8. _____
1. convenience/small grocery store	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
2. supermarket	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
3. fresh food market	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
4. hardware store	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
5. clothing & shoes store	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
6. pharmacy/drug store	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
7. book / stationary store	1. __	2. ____	3. ____	4. ____	5. ____	8. _____
8. video / audio store	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
9. library	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
10. laundry/dry cleaners	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
11. salon/barber shop	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
12. bank/credit union	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
13. post office	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
14. doctor/clinical service	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
15. Primary school	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
16. nursery schools	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
17. Chained Western or Chinese fast food restaurant (e.g., MacDonald, Café de Coral, Fairwood,)	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
18. Chinese coffee shop or noodle shop	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____
19. Chinese non-fast food restaurant	1. ____	2. ____	3. ____	4. ____	5. ____	8. _____

20. Western non-fast food restaurant (e.g., spaghetti house) 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

21. Coffee shop (e.g., Starbucks) 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

22. park 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

23. community center or elderly centre 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

24. gym or fitness facility 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

25. swimming pool 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

26. Religious places (Church, temples) 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

27. public toilet 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

28. bakery / cake shop 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

29. public transit (bus stops; MTR/KCR stations) 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

30. Hong Kong Jockey Club betting branch 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 8. _____

C. Access to services

Please choose the answer that best applies to you and your neighborhood. Both <u>local</u> and <u>within walking distance</u> mean within a 10-15 minute walk from your home.

1. Stores are within easy walking distance of my home.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. Shopping areas are easily accessible via public transport.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There are many places to go within easy walking distance of my home.

1	2	3	4
strongly	somewhat	somewhat	strongly

disagree	disagree	agree	agree

4. It is easy to walk to a transit stop (bus, MTR) from my home.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. The streets in my neighborhood are hilly, making my neighborhood difficult to walk in.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. There are major barriers to walking in my local area that make it hard to get from place to place (for example, freeways, railway lines, rivers, steep staircases, roadwork).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

7. The streets are so crowded that it is difficult to walk.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

8. I need to walk over a bridge or through a tunnel to access the nearest services.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

9. I can easily access the entrance/exit of the building I in live in (e.g., there is a lift that I can use).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

D. Streets in my neighborhood

Please choose the answer that best applies to you and your neighborhood.

1. The streets in my neighborhood have many cul-de-sacs (dead-end streets).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. The distance between intersections in my neighborhood is usually short.

1	2	3	4

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There are many alternative routes for getting from place to place in my neighborhood. (I don't have to go the same way every time.)

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

You're making great progress……keep it up!

E. Places for walking

Please choose the answer that best applies to you and your neighborhood.

1. There are sidewalks on most of the streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. There are motor vehicles parked on the sidewalks in my neighborhood making it difficult to walk.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There is a fence that separates the streets from the sidewalks in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. My neighborhood streets are well lit at night.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. There are 'hawkers' and shops on the streets and sidewalks blocking the way.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

7. The are many covered sidewalks in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

8. There are indoor, air-conditioned places (shopping malls) in my neighborhood where people can walk.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

9. The streets and sidewalks in my neighborhood are often slippery.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

10. There are sitting facilities (e.g., benches) where I can rest in my neighborhood

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

F. Neighborhood surroundings

Please choose the answer that best applies to you and your neighborhood.

1. There are trees along the streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. There are many interesting things to look at while walking in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There are many attractive natural sights in my neighborhood (such as landscaping, views).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. There are attractive buildings/homes in my neighborhood.

1	2	3	4
strongly	somewhat	somewhat	strongly

disagree	disagree	agree	agree

5. The level of air pollution in my neighborhood is often high.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. There are lots of animal droppings in my neighborhood making walking unpleasant.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

7. It is unsafe to walk in my neighborhood because of objects dropping from high-rise buildings.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

G. Traffic hazards

Please choose the answer that best applies to you and your neighborhood.

1. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. The speed of traffic on most nearby streets is usually slow (40 km/h or less).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. Most drivers exceed the posted speed limits while driving in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. There are parked vehicles in my neighborhood that block my vision and make it difficult to safely cross the road.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. I am afraid to cross the roads in my neighborhood because there are too many passing cars.

1	2	3	4
strongly	somewhat	somewhat	strongly

disagree	disagree	agree	agree

H. Safety from crime

Please choose the answer that best applies to you and your neighborhood.

1. Walkers on the streets in my neighborhood can be easily seen by other people.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. There is a high crime rate in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. The crime rate in my neighborhood makes it unsafe to go on walks <u>during the day</u>.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. The crime rate in my neighborhood makes it unsafe to go on walks <u>at night</u>.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. There are many homeless people, drug addicts and/or prostitutes in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. It would be difficult to ask for help in my neighborhood because there are not many people around.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

Appdendix 5: Research Training and Development

1. **Structural Equation Modelling Workshop**, by Institute for Health and Ageing (IHA), ACU (currently closed) November 2016.

2. **Python Workshop**, by ACU eResearch, January 2017

3. **Accelerometer Data Collection Training**, by the International Physical Activity and Environment Network (IPEN) research team from University of California, San Diego in collaboration of IHA, ACU, August 2017

4. **Project Management: Databases and Quality Control Workshop**, by the IPEN research team from University of California, San Diego in collaboration of IHA, ACU, August 2017

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