UNDERSTANDING THE RELATIONSHIP BETWEEN URBAN DESIGN AND WALKING TO INFORM SUSTAINABLE URBAN DEVELOPMENT: A CASE STUDY OF HANOI

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Degree: Doctor of Philosophy

Date of 1st submission: 1st September 2022

Date of final submission: 17th December 2022

Submitted in total fulfilment for the degree of Doctor of Philosophy

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ABSTRACT

Background

Walking is increasingly seen as a crucial instrument in promoting sustainability all over the world due to its various benefits to the health and well-being of urban citizens as well as the environment and the economy of the cities. A growing body of evidence in the literature, mostly from Western countries, shows that urban design largely influences the prevalence of walking in urban environments. However, there is a limited number of studies on the relationship between walking and urban design from low- and middle-income countries in Asia, where urban forms are traditionally more compact, complex and with multiple layers and varied urban typologies. Due to the advent of rapid motorisation and urbanisation, Asian cities are now losing their traditional walking lifestyle and instead, embracing urban development that prefers access via private motor vehicles rather than active transport modes such as walking.

Aim and objective

Choosing Hanoi as the case study, the present thesis explores the relationships between walking and urban design by investigating the prevalence, variation, and characteristics of walking across the city, and at the same time, evaluating urban design across the varying urban typologies.

Methods.

Using a multidimensional approach, four studies were conducted simultaneously across Hanoi including a travel survey focusing on walking, an urban design qualities audit, a perceived urban design survey and a study on environmental factors such as weather and pollution. The obtained data are analysed together to explore the relationship between them.

Results

The results highlighted that walking still plays an important role in Hanoi's urban transport with a high share in both the number of trips and travel time. Urban typologies and their characteristics have been found to have particular impacts on urban design and walking. Old, high-density and mixed-use urban typologies like Ancient Quarter tended to report better urban design and higher walking rates than modern but low-mix typologies like New Urban Areas. The likelihood and the prevalence of walking were also significantly associated with different factors of demographic, perceived urban

design and urban design qualities. Land use mix was found to be positively associated with both walking rates and time, suggesting it is the most important urban design feature in promoting walking. Environmental factors such as temperature, humidity, air and noise pollution did not significantly influence the prevalence of walking.

Conclusion

Overall, the study contributes to our understanding of the prevalence of walking and urban design in Hanoi, providing policymakers, planners, urban designers and architects with important insights for sustainable urban design policies, strategies and interventions.

DECLARATION

I hereby declare that the thesis comprises only my original work towards the degree of Doctor of Philosophy of The University of Melbourne and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of any educational institution, except where due acknowledgment and reference have been made in the text. I also declare that the thesis is fewer than the maximum word limit in length, exclusive of tables, maps, bibliographies and appendices.

Any contribution made to the research by others, with whom I have worked, is explicitly acknowledged in the thesis.

Signature: __(Signed)_____

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Date: 1 September 2022

PREFACE

Several sections (7.1, 7.3.1, 7.4.1, and 7.5) of Chapter 7 and Section 4.5 of Chapter 4 were published as the below article:

- Title: Evaluation of Urban Design Qualities across Five Urban Typologies in Hanoi.
- Authors: Thanh Phuong Ho, Mark Stevenson, Jason Thompson, Tuan Quoc Nguyen
- Journal: Urban Science
- Volume/issue: Vol 5, issue 4.
- DOI: https://doi.org/10.3390/urbansci5040076
- Published date: 1 October 2021
- Contributions of authors:

Author	Contribution
Thanh Phuong Ho	Conceptualisation, study design, methodology, data collection, writing.
Mark Stevenson	Study design, methodology, writing, review, editing
Jason Thompson	Methodology, writing, review, editing
Tuan Quoc Nguyen	Data collection, review, editing

All co-authors have agreed to materials from the listed publication being included in the present thesis and signed the Co-author authorisation form.

All other parts of the thesis have not been published or submitted for publication yet.

Thanh Phuong Ho was supported by Melbourne Research Scholarship.

ACKNOWLEDGMENTS

This PhD research would not have been successful without the support of my supervisors, my family, colleagues, institutions, and research participants.

Firstly, I would like to express my deepest appreciation and gratitude to my supervisors, Prof Mark Stevenson and A/Prof Jason Thompson, for their consistent guidance during my PhD journey. I have been fortunate to have had an opportunity to work under their supervision. Their enormous expertise, immense knowledge, plentiful experience, invaluable advice, continuous support, and tremendous patience were vital for the development and completion of the research covered in this thesis. They have always been available for meeting me and given me warm-hearted encouragement in both academic research and daily life. I am also very grateful for their understanding and support for my personal difficulties, especially during the Covid -19 pandemic.

I would like to thank Dr Hyungmin Kim for being my research committee member for many years. Dr Kim's guidance and constructive feedback helped me a lot in planning and analysing my research. I also wish to express my appreciation and gratitude to Dr Tuan Quoc Nguyen and his students for their support during my fieldwork in Hanoi. Dr Nguyen provided invaluable insight and advice about Hanoi, which was crucial in designing and conducting this study. I would also like to acknowledge, with thanks, all the research participants in Hanoi for their time and contributions.

I am grateful to my colleagues at Transport, Health and Urban Design Research Lab (THUD). It has been always enjoyable and satisfying to be part of THUD for many years, sharing unforgettable times and moments in the work as well as in social settings.

I wish to express my appreciation to the Faculty of Architecture, Building and Planning, Melbourne School of Design, University of Melbourne for sponsoring me with a scholarship and hosting me during my candidature. I would like to give special thanks to Ms Jane Trewin and Ms Caroline Deacon for their prompt and tremendous support in every aspect of my PhD journey.

I would also like to convey my heartfelt thanks and deepest love to my wife, and my lovely children. Without their tremendous love, understanding and encouragement in the past few years, it would be impossible for me to complete my study. My special thanks and love also go to my parent, my sister, my mother-in-law and brother-and sisters-in-law, and all others in my family for their constant care, support and encouragement.

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CHAPTER 1 INTRODUCTION

1.1 Overview

Living in a city brings many opportunities including employment, education, and housing, however, it can also contribute to adverse health outcomes. Unsustainable or unplanned urban development can increase exposure to health risks such as air pollution and physical inactivity, which contribute to 41 million deaths per year attributed to non-communicable diseases (NCDs) (WHO, 2022). In recent years, research has highlighted how urban design and transport policies can deliver beneficial health outcomes for city residents. Concepts like compact cities or transit-oriented developments (TOD), which promote mixed land use, high residential density, and public transport, have been shown to bring significant health benefits (Stevenson et al., 2016). Well-designed urban spaces not only improve a city's competitiveness and attractiveness, but they also reduce the need for motorized vehicles (and therefore reduce air pollution) along with improved physical activity, particularly walking (Suzuki, Cervero, & Iuchi, 2013). City planners and policy-makers, who have the capacity to create or change cities need to prioritise reducing urban health risks and maximising health co-benefits while strengthening the mobility of city residents (Stevenson et al., 2016). This goal requires thorough knowledge and understanding of urban design and urban transport, especially in low- and middle-income countries which have unique urban structures and processes of urbanisation. This research explores the prevalence of walking and its relationship with urban design in the city of Hanoi, a city in a lower middle-income Asian country, seeking valuable information to guide future urban development and ultimately, enhance the health of residents.

1.2 Background

1.2.1 Rapid urbanisation

Today, more than half of the world's population lives in urban areas. In recent decades, the world's urban population has been rising faster than ever before, growing rapidly from 751 million in 1950 to almost 4.2 billion in 2018 (UN, 2018). It is expected that by 2050, this proportion will reach 68% which means there will be an additional 2.5 billion people living in urban areas and 90% of this addition will occur in Africa and Asia (UN, 2018). The increase in the world's urban population is expected to occur in a few countries namely, Nigeria, India, and China with the focus of urbanisation shifting from

developed countries to developing countries (UN, 2018). The United Nations projects that the world will have 43 megacities (cities with populations exceeding 10 million population) by 2030 and most of these cities will be in developing regions (UN, 2018). Well-managed urbanisation can always bring significant benefits for development however unplanned and rapid urbanisation is often linked to environmental problems and population demands that exceed service capacity (Moore, Gould, & Keary, 2003) which creates major challenges including poverty, infrastructure, health, climate change and social instability (World Economic Forum, 2015).

1.2.2 The burden of non-communicable disease

The conditions of urbanisation raise serious concerns regarding urban health. Major threats to health in today's cities are infectious diseases namely HIV/AIDS, pneumonia, diarrhoeal diseases and most recently Covid-19; non-communicable diseases (NCDs) diseases such as asthma, heart disease, cancer, diabetes; violence and injuries. Among them, NCDs are a significant challenge to urban health given that millions of people die each year from NCDs (WHO, 2022). According to the WHO, NCDs are the result of a combination of genetic, environmental, physiological, and behavioural factors (World Health Organization, 2014). In 2005 NCDs accounted for 60% of all deaths globally (35 million deaths) (Habib & Saha, 2010). Three quarters (77%) of all deaths from NCDs, and the majority of premature deaths (82%), occurred in low- and middle-income countries (WHO, 2014). A growing prevalence of NCDs associated with overweight and obesity among residents of cities is also found in developing countries in Asia (Ng et al., 2014; Ramachandran & Chamukuttan Snehalatha, 2010). In 2010, research by Tuan Nguyen and Minh Hoang showed that NCDs were responsible for 318,000 deaths (72% of total deaths) in Vietnam where adults had an increased prevalence of overweight and obesity (2.3% in 1993 to 15% in 2015) and hypertension (15% in 2002 to 20% in 2015) (Nguyen & Hoang, 2018). The WHO has prioritized four behavioural risk factors for NCDs namely, physical inactivity, unhealthy diet, tobacco use, and the harmful use of alcohol (World Health Organization, 2014). Understanding and reducing the prevalence of physical inactivity in urban environments to prevent this growing burden of NCDs has never been more urgent for governments and policymakers.

1.2.3 Increasing levels of physical inactivity

According to Caspersen et al. (Caspersen, Powell, & Christenson, 1985), the definition of physical activity is “any bodily movement produced by skeletal muscles that result in energy expenditure above resting level”. Moderate-intensity activity, which includes cycling, walking, and various forms of light exercise, are considered as physical activity. Regular physical activity has substantial benefits for health (WHO, 2020). Insufficient physical activity is a key risk factor for NCDs, and the fourth leading cause of early death globally (WHO, 2014). Strain et al. (2020) estimated that at least 3.9 million early deaths are being averted worldwide every year by people being physically active. However, because of modernisation and industrialisation, populations have become increasingly sedentary, resulting in a significant decline in levels of physical activity and numerous negative health outcomes. Sedentary behaviour during work-time and the lack of physical activity during leisure time are two main reasons for the current decline in physical activity levels. Likewise, the use of "passive" modes of transport like cars has increased levels of physical inactivity. During the process of urbanisation, physical activity is discouraged by various urban factors: high-density traffic, pollution, violence, and lack of walkable spaces and sports/recreation facilities (WHO, 2014). Decisions made by individuals to walk to destinations or not are therefore driven by more than just individual preferences. Multi-disciplinary, and culturally relevant urban design and transport policies need to be implemented to promote physical activity, globally.

1.2.4 Active transport and physical inactivity

In recent years, there is an increased emphasis on the potential for urban design and transport to use active transport to promote physical activity (Zapata-Diomedi et al., 2017). Physical activity undertaken as a means of transport is the broad definition of active transport (National Public Health Partnership, 2005). Walking or cycling are the most popular forms of active mobility, although there are also other forms of active mobility such as skateboarding, kick scooter, roller skating, etc. Since people often engage in walking or cycling on the way to metro stations or bus or tram stops, the use of public transport is considered to be one form of active transport (National Public Health Partnership, 2005).

Several studies have shown that active transport has a protective impact on our health. In a meta-analysis of the nexus between active transport and cardiovascular risk in 2008, Hamer and Chida reported that active commuting helps reduce 11% of overall

cardiovascular risk (Hamer & Chida, 2008). They also estimated that all-cause mortality risk can be reduced by 31% by active transport (Hamer & Chida, 2007). Positive associations of active transport with obesity, fitness and cardiovascular disease (CVD) risk factors have also been confirmed in research by Gordon-Larsen et al (2009). As with most forms of physical activity, active transport has injury risks and walking and cycling have higher risks of injury per kilometre travelled than driving a car (Elvik, 2009). However, the long-term benefits of increased walking and cycling were proven to be able to far outweigh road injury risks (Mizdrak, Blakely, Cleghorn, & Cobiac, 2019).

1.2.5 Walking and our cities

Walking is considered one of the most energy efficient and sustainable ways to move around. It is also the primary mode of active transport in cities. Walking is increasingly seen as a sustainable solution for issues on urban transportation, social inclusion, and public health. There is a growing body of literature highlighting the benefits that walking brings to urban citizens. Miner (2003), Bogumil (2015) and Stevenson et al. (2016) have listed an array of positive impacts of walking on the well-being of urban dwellers (Bogumil, 2015; Miner, 2003; Stevenson et al., 2016). Walking creates no noise or air pollution and at the same time acts as a valuable cardiovascular exercise. Walking takes up a far smaller amount of urban space in comparison to motor vehicles and car parking. Moreover, walking is free for all people, so it's economical, costing far less than the private car and public transport (Speck, 2012). Despite the potential co-benefits associated with walking in urban areas, the advent of rapid motorisation associated with private motor vehicle use and the investment in extensive road networks has resulted in a degraded pedestrian environment that frequently discourages walking. Research by Pucher & Buehler (2010) highlights that walking trips have declined significantly in the United States, Western European countries and Australia in the past four decades. In contrast, walking still acts as a key mode of transport in many cities of developing countries in Asia (Ng et al., 2012). Nonetheless, walking as a transport mode is also declining in Asian cities as a consequence of rapid urban development and motorisation (Leather, Fabian, Gota, & Mejia, 2011). In most Asian cities, it is expected that people prefer to drive rather than walk even though Asian cities traditionally relied on walking, cycling and public transport for daily travel (Leather et al., 2011). Asian cities are losing their traditional walking lifestyle. Instead, they are

embracing urban development that preferences access via private motor vehicles rather than active transport modes such as walking and cycling.

1.2.6 Urban design, walking and health

Urban design is related to the appearance, arrangement, and function of suburbs, towns and cities and is considered as "both process and outcome of creating spaces in which people live, engage with each other and the physical environment around them" (Major Cities Unit, 2011). In other words, the urban design aims to deal with the relationship between people and places, nature and the built fabric. Childs (2010) stated that the main concept of urban design is 'the shaping of parts of settlements such as the relationships between multiple built-forms, building typologies, public space, streets and other infrastructure. Madanipour (2004) argued that urban design not only deals with appearances but also with the spatial organisation of urban space and the processes of shaping cities. However, Appleyard (1982) believed that there never could be a single definition of urban design because of the existence of different kinds of urban design practice and each has its own kind of projects, arrays of skills and criteria for success.

During the industrial revolution in the 19th century, the effect of urban design on health was via the movement called Sanitary Reform. The improvement in sanitation and housing together with the separation of industrial zones from residential zones in many European cities successfully reduced the spread of infectious diseases (Lowe, Boulange, & Giles-Corti, 2014). The nexus between urban design and health has been established from this movement. In the early 20th century, especially in North America, people started to move to the suburbs to avoid traffic congestion, crime, and other urban problems, and to have homes with greater square footage (Resnik, 2010). This urbanisation trend, which is later referred to as urban sprawl, has created a car-dependent lifestyle and the separation of land uses in the most extreme expansion of residential suburbs (Lowe et al., 2014). There is considerable evidence that urban sprawl has unintended negative consequences for human health including associations with cardiovascular disease, diabetes, obesity and respiratory disease (Ewing, Meakins, Hamidi, & Nelson, 2014; Hamidi, Ewing, Tatalovich, Grace, & Berrigan, 2018)

Recently, there has been an increasing focus on understanding how urban design and planning, directly and indirectly, affect population health, often through the mechanism of increases in physical activities facilitated by more active transport. For example, the Lancet Series "Urban design, transport, and health" investigates the role and opportunity of urban design and transport to promote health and well-being (Stevenson

et al., 2016). Five local urban design interventions were explored to enhance population health including design, density, distance to transit, diversity and desirability (Stevenson et al., 2016). In this Lancet Series, a cross-sectional study conducted across a wide variety of cities has shown considerable health gains by encouraging compact cities (Stevenson et al., 2016). Mixed land use, high residential densities, good street connectivity, and sufficient active transport infrastructure are also proved to be connected with higher levels of walking for transport in many other studies (Giles-Corti, Ryan, & Sarah Foster, 2012; Sallis, Millstein, & Carlson, 2011). In addition, shorter distances to public transport stops are an important factor to increase the prevalence of walking (Ewing & Cervero, 2010). However, the study by Brown et al. (2007) has reported significant differences in the walkability of route segments across the areas that have the same walkability with regard to macro-scale measures. Several other studies also highlighted how micro-scale urban design features can improve walkers' experience and lead to more walking (Foltête & Piombini, 2007; Gallimore, Brown, & Werner, 2011; Weinstein Agrawal, Schlossberg, & Irvin, 2008). Urban design researchers suggested that micro-scale urban design should be an important additional focus of walkability research (Adkins, Dill, Luhr, & Neal, 2012; Harris, Lecy, Hipp, Brownson, & Parra, 2013). Furthermore, Barton (2009) stated that the relationship between health and urban environment is complex. Individual health in urban environments is influenced by many factors including living and working conditions, social and community conditions, socioeconomic and cultural conditions, and environmental (both built and natural) conditions (Croucher, Wallace, & Wallace, 2012).

1.3 Rationales for the study

Asian cities today are facing major threats to the health of their residents. A significant threat is the increasing rates of physical inactivity as a consequence of rapid motorisation in which city residents shun active transport modes in preference of private motor vehicles.

1.3.1 Cities in transport crisis: Hanoi the capital of Vietnam

Hanoi, the capital of Vietnam, a developing country in Asia, is experiencing considerable population growth. In relation to the city's transportation system, it is a city in crisis with considerable traffic congestion, traffic emissions and associated road deaths and serious injury. With the road network comprising fewer than 7 per cent of the city area and with motorcycles the predominant mode of transport, highlighting the very high rates of personal mobility, the road network is inadequate (World Bank, 2018). Almost 2

million motorcyclists make 60 per cent of all trips in the city (World Bank, 2018). The public transit system in Hanoi comprises buses and only one metro line, with public transit transporting fewer than 10 per cent of total trips (World Bank, 2018). Added to the transport challenges is the inadequate traffic management strategies. For example, many intersections in the city are not controlled either by design (such as roundabouts) or via traffic signals.

The limitation of Hanoi's transport system extends beyond just getting around the city for reasons of recreation and employment. Geertman (2010) states that, in Hanoi, cars and motorcycles are affecting residents' quality of life, including their health and well-being. While the topic of urban health and walking has been taken into account in many developed cities, it has received scant attention from planners and policymakers in Vietnam whose focus tends to be related to alleviating increasing demands for housing and transport infrastructure. Geertman (2010) also highlights the increasing car-based urban development in Hanoi with an aim to commute faster, undertake more business and be more productive. As a result, transportation systems are only optimized for motorized traffic and impose dangers on those who walk or cycle. In a survey for the Asian Development Bank, James Leather and colleagues (2011) reported that the City Administration Office, the City Development Planning Office, the Auto Department, and the Air Quality Agency in Hanoi were unclear on whose responsibility it was for delivering and maintaining footpaths in the city of Hanoi. This lack of focus highlights the urgency to investigate the relationship between urban design and walking so that strategies that will facilitate walking as a legitimate transport mode in Hanoi can be implemented and thereby promote the health of Hanoi's city residents.

1.3.2 Unique urban structures, characteristics, and culture

Urban sprawl is one of the most visible urban development trends in North American and Australasian cities. According to Ewing (2006), urban sprawl is characterised by: strip development, low-density or single-use development, leapfrog development, and scattered development. Although several Asian cities such as Beijing are following this path, many Asian cities have their unique urban structures and characteristics which differ from the sprawling, heavily motorized cities in the US and Australia. These main differences were outlined by Peter Sanders (2013) when he compared Hanoi with San Francisco; three distinct differences between the two cities were observed: the difference in population density (very dense versus low dense), the

difference in the mode of transport (motorbikes versus cars), and the difference in culture (collective culture versus individual culture). These differences in urban structure, transport and culture greatly affect the distribution of walkable spaces and how people move around the city. It is important, therefore, to explore the impact of these elements on urban walking and to identify which impacts should be encouraged and which should be restricted to gain maximum health benefits for the residents of Hanoi.

1.3.3 The complex history of development

The long and complex history of development in Hanoi should not be neglected in the process of urban planning practice and research. The 1000-year-old city has gone through many turbulent times of feudalism (1010 – 1858), colonialism (1858-1954), two wars (1945–1976) and poverty, which has left complicated layers in urban form and transport systems. However, it has also created a unique lifestyle and culture. Hanoi residents traditionally relied on walking for daily travel in the feudal era when the street network of the city was mostly narrow and comprised short, commercial streets. The city still had relatively low motorisation levels during French colonialism although the French constructed a new street network with larger boulevards. In the early 80s, bicycles still dominated the streets of Hanoi (Hansen, 2016). However, rapid development in Vietnam from 1986 due to the economic reforms (Doi Moi) led to a notable transformation of Hanoi and nowhere are these changes as visible as in urban transport. Another important event that contributed largely to the transformation of Hanoi is the expansion in 2008 when the city tripled its land area by encompassing the neighbouring provinces and districts. In less than 20 years, the number of motorcycles has increased tenfold and reached a record of 4 million motorcycles (Hansen, 2016). The result of this rapid growth also can be seen in the increased levels of air pollution, and a low share of public transport and active transport (JICA, 2007). The dramatic transformation happened not only in urban transport but also in urban form, land use and the economy. All of these changes, in turn, affect the daily lifestyle of citizens. It is important to understand the historical urban context of Hanoi and assess how such varied contexts affect walking in Hanoi. Exploring these contexts will elucidate effective ways of maximizing the likelihood of walking and thereby enhance the health of city residents.

1.3.4 Halting urban sprawl and seizing opportunities for healthier development

A further rationale for this research relates to timing. The current period in Hanoi is most suitable to undertake research investigating strategies to enhance the environment; importantly, supporting a city that promotes urban design that is conducive to active transport. Hanoi is at a turning point in urban development and has an opportunity to determine a pathway albeit not the same as other developed cities or developing Asian cities. Urbanisation in Asia is happening faster than it was in Europe a century ago (Boquet, 2010). It took London 130 years to grow to 8 million people, while Bangkok only needed 45 years, Dhaka 37, and Seoul 25 years (Boquet, 2010). The transportation systems in many cities in Asia, like Beijing and Kuala Lumpur, have been developed with the car as a dominant means of transportation. Beijing, once a city of bicycles in the late 1970s, has become a city of cars, with more than 3 million cars on the streets each day (Boquet, 2010). Kuala Lumpur is also one of the most car-dependent Asian cities (Barter, 2000) with 91% of residents using private motor vehicles (Boquet, 2010). As a result, most of the aforementioned Asian cities have become polluted due to the dominance of cars or lost much of their unique urban fabric to transit systems (Sanders, 2013).

However, Hanoi is in an early phase of urban transport development, and therefore there is an opportunity to study urban design and explore the possibilities for a predominance in active transport - namely walking - which promotes not only sustainable transport, and reduced transport emissions but also enhanced population health. Findings from a systematic assessment of urban design and walking prevalence can influence planners and decision makers to avoid the negative consequences of current or proposed urban development that could assist to prevent Hanoi from transforming into another car-dependent Asian city.

1.3.5 Summary of rationale

Having unique urban structures and historical context, Hanoi has significant opportunities to optimize the urban design to promote urban walking, which will not only enhance the health of its inhabitants but also contribute to solving the urban transport problems. Understanding the relationship between urban design and active transport in Hanoi will provide policymakers, urban planners, and transport planners useful insights when developing urban development plans and policies. The findings will also contribute considerably to the limited literature on active transport, urban planning and health in Asian low- and middle-income countries.

1.4 Aims and objectives

1.4.1 Aims

The primary aim of the research is to investigate the prevalence of walking, the characteristics of urban design, and the relationship between urban design and walking in the context of Hanoi, Vietnam.

1.4.2 Objectives.

To examine this broad question, seven objectives have been established:

- Explore the prevalence of walking in Hanoi
- The variation and characteristics of walking.
- Identify the association between walking and demographic characteristics of residents
- Identify the association between walking and five urban typologies of Hanoi
- Explore the variation of perceived urban design in the five urban typologies and how it is associated with the prevalence of walking
- Explore the variation of urban design qualities in the five urban typologies and how it is associated with the prevalence of walking
- Explore the impacts of environmental factors (temperature, humidity, air and noise pollution) on walking.

1.5 Research framework

To achieve the objectives set out above, a research framework is established. The research framework aims to provide a means whereby the impact of urban design, which consists of perceived urban design and urban design qualities, on the prevalence of walking. In addition, the research investigates the influences of demographic characteristics and environmental factors on the prevalence of walking. The framework is illustrated in Figure 1-1 below.

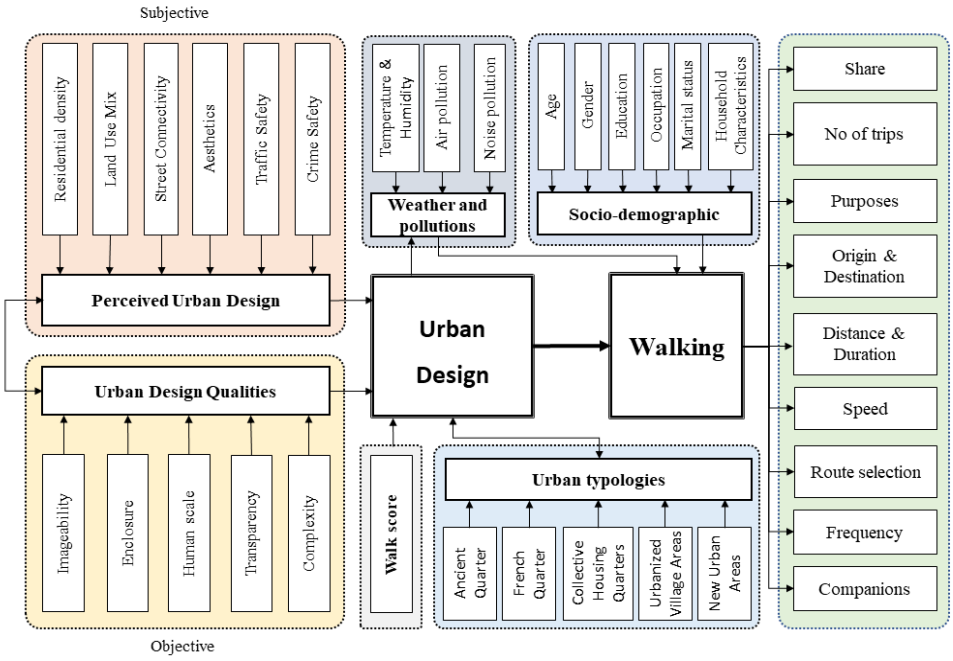

Figure 1-1 Research Framework

1.6 Structure of the thesis

This thesis consists of eight chapters along with supplemental materials provided in the Appendices.

- Chapter 1 describes the background information, study rationales, aims, objectives, research framework and the structure of the thesis.
- Chapter 2 reviews the literature related to walking, and urban design as well as the relationship between them. Chapter 2 also discusses the limitations of the literature that leads to the need for the present thesis.
- Chapter 3 outlines the context of the case study city (Hanoi) in terms of the history of urban development, typical urban typologies, urban transport, and urban walking.
- Chapter 4 describes the research methods of studies included in this research. The chapter outlines the research design, sampling process, data collection, pilot study, instrument adaptations, and analysis methods.
- Chapter 5 focuses on the prevalence and the characteristics of walking in Hanoi. The chapter also highlights the association between walking and demographic characteristics as well as urban typologies
- Chapter 6 focuses on perceived urban design across typical urban typologies of Hanoi and their influence on walking. The chapter outlines the variations

in perceived urban design and analyses the relationship between perceived urban design and walking.

- Chapter 7 focuses on the urban design qualities across five urban typologies in Hanoi and their association with walking. The chapter also analyses the environmental factors using data obtained from the sensors and meters installed across Hanoi to see their variation across the urban typologies and their relationship with walking.
- Chapter 8 summarises the main findings, discusses the limitations of the research, and suggests potential future research and recommendations for policy implications.

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CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Chapter 2 provides a detailed review of the literature related to walking, urban design and their relationship. The first section of the literature review discusses the history, forms, characteristics, and benefits of walking as well as methods to measure it. The second section focuses on the relationship between walking and socio-demographic characteristics. The third section of the literature review discusses the urban design and its impact on walking as well as methods to measure urban design factors that influence walking. The fourth section reviewed the literature related to urban design and walking in the Asia context. Five sections discuss the nexus between walking and environmental factors such as weather and pollution. The final section identifies and discusses the gap and limitations of literature on walking and urban design, providing reasons for conducting the present research.

2.2 Walking: history, characteristics, and benefits

2.2.1 History of walking

2.2.1.1 Origin of walking

More than 4.4 million years ago, the first early hominins, or modern human ancestors, developed walking behaviour that separated humans from the four-legged animals (Harcourt-Smith, 2010; Napier, 1967). Although it's unclear why primitive humans started to walk upright, whether it was to see predators quickly, travel faster, or adapt to climatic changes, walking certainly freed their hands for making, carrying, and catching food and tools, which was important in human evolution (Harcourt-Smith, 2010). Since then, humans have utilised walking for varied reasons and walking continued to be the primary, if not sole means of land transportation for the next three million years. Although horses were first domesticated in around 3500 BC, followed by wheeled carts invented by the Mesopotamians in 3200 BC and horse-drawn carriages were used some 5,000 years later, walking remains a primary means of transport in all over the world. Napoleon and his army of about 100,000 men walked from Paris to Moscow then returned on in the early 1800s. Nothing could replace walking as the primary method of getting around until the early 20th century.

2.2.1.2 History of urban walking.

2.2.1.2.1 Walking city

Prior to 1850, pedestrians still dominated the streets of cities over the world. Cities in this period were referred to as "the walking city" characterized by highly compact urban form; mixed patterns of land use; narrow streets and alleyways; a short journey to work as seen in Figure 2-1 (Newman & Hogan, 1987). Most cities can be walked from one side to the other in one hour and all destinations can be reached within about a half-hour walk. Thus a "walking city" often grew out no more than 5-8 km in diameter with densities from 100 to 200 people per hectare. There were few means of transport other than walking or on horseback.

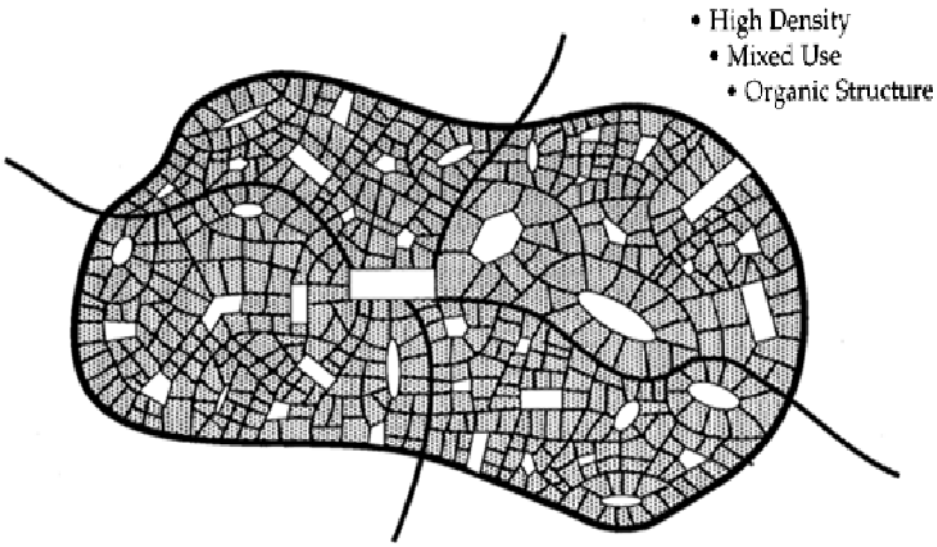

Figure 2-1 The traditional walking city.
Source: Newman and Kenworthy (1996)

2.2.1.2.2 Transit city

The Industrial Revolution has ended the "walking city" and allowed the "transit city" to emerge. In the 1830s, steam locomotives were used but they were too large and too expensive to use as inner-city transportation. Later in this period, omnibuses, cable cars, and horsecars appeared on streets as the forerunners to electric trams which became very popular. With the pipes to channel water and trains and trams systems to carry people, the middle and upper classes moved away from city centres to the suburbs to avoid pollution while the working classes, by contrast, remained near the core and close to industrial workplaces since they had little or no access to public transportation. In the "transit city", the trains generally created sub-centres at railway stations and trams created

linear development that followed the routes (Figure 2-3). Those rail-based suburbs and tram suburbs had medium-density, mixed-use areas and walkable environments just like a "walking city"(Newman & Kenworthy, 1996). The "transit city" could spread 20-30km along those corridors and had an overall density of between 50 to 100 people per ha (Newman & Kenworthy, 1996). Transit cities maintained high rates of walking because walkable environments were also critical to the functioning of the transit system (Newman & Hogan, 1987). The more walking accessible (which often means more people living and/or working in close proximity) to the transit facilities, the greater the likelihood the service will be utilized (O'Sullivan & Morrall, 1996; Weinstein Agrawal, Schlossberg, & Irvin, 2008).

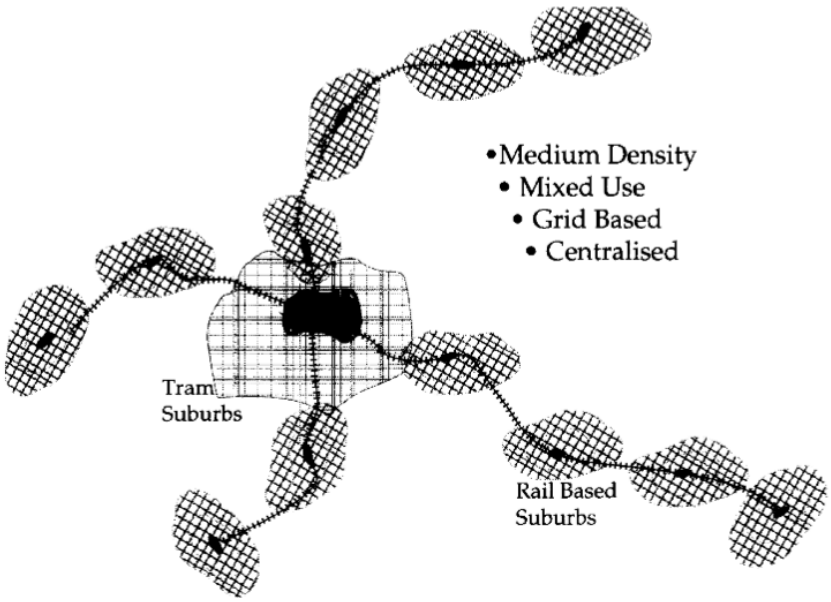

Figure 2-2 Transit city.
Source: Newman and Kenworthy (1996)

2.2.1.2.3 The automobile city

Since Henry Ford released the first Model T in 1908 from his production line, making cars became faster, more efficient, and cheaper. Cars then began to spread widely and soon dominated streets in the USA and then Europe, especially after 1920. The introduction of the mass-produced car represented a revolution in mobility and convenience and created new freedom over space and time that became the momentum for urban change. Especially after 1940, cars colonised the space of everyday human life in many Western cities and became the mode of transport that shaped the city, creating a new city type labelled as the "automobile city" by Newman and Hogan (1987). The

automobile city could spread 50 km from the city centre and reduce the density to between 10 and 20 people per ha (Figure 2-4). The most visible phenomenon of the automobile era was “urban sprawl” referred to as the rapid expansion of the geographic extent of cities characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation.

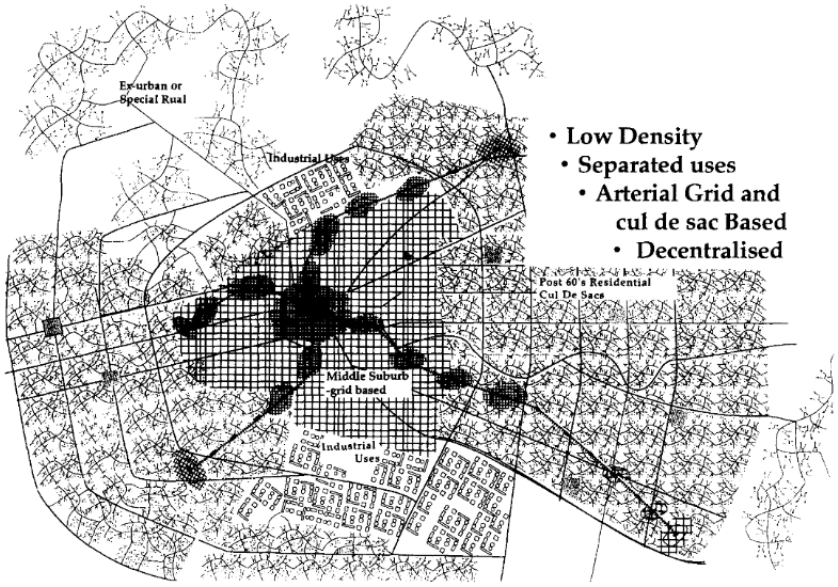

Figure 2-3 Automobile city.

Source: Newman and Kenworthy (1996)

2.2.1.2.4 The fall of urban walking

The automobile city has been criticized for many environmental, economic and social problems and the lack of walkability is often considered the underlying root for all of those problems (Newman, 2003). Gradually, city residents became more discouraged from walking and walking trips consequently decreased markedly. Research by Pucher & Buehler (2010) highlights that walking trips have declined significantly in the United States, Western European countries and Australia in the past four decades. Particularly, in Britain, walking trip rates decreased by 19% during the period from 1975 to 2001 as well in the period from 2005 to 2015 while distance walked decreased by 26% in the former period and 8% in the latter one (Department of Transport, 2002, 2018). In Germany, there has been a decline of 10% in the share of walking trips over 13 years from 1976 to 1989 (Hass-Klau, 2003). The decline in children’s active travel to school was also reported all over the world, ranging from 7% in Brazil (from 2002 to 2007) (Costa, Silva, Schmoelz, Campos, & de Assis, 2012) and Switzerland (from 1994 to 2005) (Grize, Bringolf-Isler, Martin, & Braun-Fahrländer, 2010), 12% in Canada (from 1985 to

1996)(Rock, 1997), 23% in the UK (from 1975 to 2001)(Black, Collins, & Snell, 2001; Mackett, 2001) and as much as 35% in the US (from 1969 to 2009)(Ham, Martin, & Kohl, 2008; McDonald, Brown, Marchetti, & Pedroso, 2011).

2.2.1.2.5 The rise of walking awareness

In the 1960s, urbanists, designers and theorists like Jane Jacobs, Lewis Mumford, William H. Whyte and Jan Gehl criticized automobile-dominated urban planning for having forgotten life in the city. They promoted the idea of again designing cities for people with human-focused and sustainable approaches (Gehl, 1987; Jacobs, 1961; Mumford, 1961; Whyte, 2012). However, awareness of the importance of walking in the city has only recently risen sharply with various research and studies outlining the benefits of walking as well as the strong relationship between urban design, active transport and the health of populations (Claris, Scopelliti, Luebkeman, & Hargrave, 2016). For example, research by Stevenson et al. (2016) conducted across a wide variety of cities in the world has shown considerable health gains by encouraging compact cities that support active transport like walking. Jeff Speck, with his famous books such as “Walkable City: How Downtown Can Save America, One Step at a Time” or “Walkable City Rules: 101 Steps to Making Better Places”, highlighted the importance of walking and how walking can save America's cities from their several problems and make them better places for people. On a global scale, there are more and more institutions and organizations dedicated to promoting walking. For example, Walk 21, an international platform for inclusive discussion in walking, development of the best practice of walking, delivery of new initiatives through the international conference series, sponsored walking research projects and local consultancy services. Cities around the world are also beginning to realise that they could have healthier, happier citizens and thriving streets and public spaces by promoting walking (Claris et al., 2016). More and more cities endeavour to become more walkable and encourage the use of active transport (Lefebvre-Ropars & Morency, 2018). In Europe, the emphasis on the pedestrian environment has been supported by the European Charter of Pedestrians’ Rights, which was adopted in 1988 by the European Parliament (Papaioannou, Basbas, Konstantinidou, & Politis, 2009). However, it will not be easy to achieve walkable cities, especially in countries like the U.S where cities have been built according to automobile-dominated standards (Southworth, 2006). Thus, the path to reclaiming walkable cities will require time and persistence.

2.2.2 Forms of walking

Although people can walk for different reasons and purposes, there are two dominant purposes namely, walking for transport and walking for recreation.

2.2.2.1 Walking for transport

Walking has always been the most popular, affordable, and sustainable mode of transport available to city residents. Walking for transport can be defined as a means of getting to utilitarian destinations like workplaces, schools, or shops. Walking is the only mode of transport that doesn't require the use of vehicles and is sometimes the only choice of transport, especially for people of low socioeconomic or minority societies where other modes of transport are inaccessible or unaffordable. Therefore, walking can be considered the most democratic means of transportation because it is accessible to anyone regardless of their age, gender, ethnicity, religion or socioeconomic status except in the case of physical disability or injury (Delclòs-Alió et al., 2022).

Transport-related walking can be divided into commuting walking and non-commuting walking. Commuting walking includes walking to/from workplaces and schools, while non-commuting walking involves other destinations like shops. Commuting and non-commuting walking are significantly different but often reported in the same way in literature (Liu, Zhou, & Xiao, 2021), which can be misleading often resulting in generic solutions being provided to both forms of transport-related walking. Commuting trips are more spatially and temporally stable since people often have to commute at the same times of the day and to the same places, while non-commuting travel can be more flexible in terms of destinations and times (Ding, Liu, Zhang, Yang, & Wang, 2017). Non-commuting walking has also been found to be more frequent and longer than commuting walking (Liu et al., 2021). Also, nearness to utilitarian destinations is only essential for non-commuting walking not for commuting walking (Gao, Kamphuis, Helbich, & Ettema, 2020).

Although walking is the most common mode of movement, it is not always given the same level of attention or priority among city planners as vehicle-based modes. The prevalence of walking trips is also often underestimated. One of the reasons is the limited information and available instruments for walking (Mitchell & Stokes, 1982). Mitchell and Stokes explained that information about walking is only limited to areas where government bodies have been required to take an interest, or where commercial investments rely upon pedestrian movement. Also, walking is mainly used for short trips

but the national travel surveys often do not register shorter trips, therefore walking data is often absent at the country level (Wittink, 2001).

Another reason why the prevalence of walking is underestimated is the fact that walking is an essential component of almost all trips. Public transport such as trains and buses require walking both for access and for movement within the vehicles themselves. Private transport also includes a walking component between homes, destinations, parking places, and vehicles. However, people often don't realize how often they walk between modes of transport and therefore, they don't report the walking component of public transport trips (Blomberg, Jordan, Killingsworth, & Konheim, 2000).

Despite being underestimated, walking for transport still plays a vital role and has enormous potential in urban mobility. Although the proportion of walking trips is extremely low in car-dominated countries such as the United States, Canada, or Australia, walking is substantially higher in European and Asian countries (Bassett, Pucher, Buehler, Thompson, & Crouter, 2008; Bassett, Wyatt, Thompson, Peters, & Hill, 2010). Survey data from seven European countries show that 15-30% of all trips are made by walking and that share is up to 40% for trips under 5km (Wittink, 2001). In Asia, the walking mode share is even higher, ranging from 40% in Pondicherry, India to as high as 63% in Chongqing, Peoples Republic of China (Leather, Fabian, Gota, & Mejia, 2011b).

In low-income countries, a large proportion of the population cannot afford even subsidised public transport (buses) and low-cost bicycles, and walking is the only option for commuting (Tiwari, 2001). Along with the poor, the elderly and handicapped people are often dependent on walking since there are few alternative modes of transportation available to them (Braun & Roddin, 1978). These groups of populations can be referred to as 'captive pedestrians' which means they walk because "they have to" and not because "they want to" (Braun & Roddin, 1978; Mateo-Babiano, 2016; Tiwari, 2001).

In many countries, the majority of trips made by car are trips with short distances that are feasible for walking. According to the American National Household Travel Survey 2017, half of all trips and more than 35% of vehicle trips are under two miles (McGuckin & Fucci, 2018). In the same sense, over 46% of journeys in the UK are less than two miles but 60% of those trips are made by motor vehicle (Transport Committee, 2019). In low and middle-income countries, motorised two wheelers are popular and have a large mode share in the cities. In Delhi, motorised two wheelers take up to 66% of the vehicular fleet and account for about one-third of short trips (1 km to 6 km) (Tiwari, 2002). Similarly, the share of motorcycles reaches almost 90% of mode share in trips

from 1 km to 5 km in Hanoi (Tran, Chikaraishi, Quynh Huong Pham, Zhang, & Fujiwara, 2015), and 16% of motorcycle trips are less than two kilometres (Tran & Schlyter, 2010). Walking has immense potential to replace automobile vehicles and motorised two wheelers on short-distance trips.

2.2.2.2 Walking for recreation

Recreational walking is defined as walking for the primary purpose of fitness, health, or physical recreation (Hekler, Castro, Buman, & King, 2012). It can range from fast walking for exercise to relaxed walking within a recreation area. Recreational walking can also be defined as walking that has no destination (Kang, Moudon, Hurvitz, & Saelens, 2017). For example, a person can walk around their neighbourhood or a park without any destination in mind.

Throughout the literature, walking has always been reported as the most common form of exercise and leisure-time activity in the US, Canada, Australia, European and Asian countries. Walking is one of the easiest and most affordable exercises because it can be performed at any time and place and requires no special skill, equipment or training (Richardson et al., 2005). More importantly, the risk of injury when walking is small in comparison with other forms of exercise (Blomberg et al., 2000). Walking is estimated to use 3.5 times the amount of energy compared to sitting quietly, which places walking in the range of moderate physical activity (Beavis & Moodie, 2014). People can also walk as a competitive sport. Long-distance walking competitions were very popular in Europe and America between 1860 and 1903 when walkers could earn relatively more than today's basketball players. Many types of walking sports such as racewalking, speed walking, power walking have been invented and practiced. Not all recreational walking is for exercising, people can walk for the pure purpose of leisure in their free time. In that case, walking is associated with pleasant feelings and rewarding experiences (Zurawik, 2020). Of course, it's not necessary to differentiate walking for leisure from walking for fitness since people can also have positive feelings when exercising.

2.2.2.3 Walking trip characteristics

In the literature, both walking for recreation and walking for transport are different not only in terms of walking purposes but also in trip frequencies, origins and destinations, durations, distances, speed as well as related built environment attributes (Spinney, Millward, & Scott, 2012). Walking for transportation has a higher proportion and trip frequencies than recreational walking (Spinney et al., 2012). Although most

walking trips take place within a distance of 1km, transport-related walking trips are often shorter and faster (from 9% to 12%) than recreational walking trips (Kang et al., 2017; Millward, Spinney, & Scott, 2013). From the standpoint of transportation, where fixed and tight schedules are often required, shorter time and distance, or in other words, efficiency, is one of the most critical considerations (Abdullah & Al-Qemaqchi, 2021). However, walking distance and time are only ranked fifth of the most essential factors for recreational walking, while experiential factors are more important (Bunds, Casper, Hipp, & Koenigstorfer, 2019).

In terms of origin and destinations, the study by Spinney et al (2012) found that home-based trips account for more than two-thirds of recreational walks but only one-fifth of transport walks. They argued that walking for transport is most likely to originate at the workplace or school, therefore research should be extended out of near-home areas scope to fully understand the influence of the built environment on walking behaviour (Spinney et al., 2012).

When health benefits are the aim of the research, researchers have focused on walking for recreation more than walking for transport (Spinney et al., 2012). However, compared to walking for recreation, more evidence of the link between the built environment and walking for transportation has been shown (du Toit, Cerin, Leslie, & Owen, 2007; Rodríguez, Khattak, & Evenson, 2006; Saelens & Handy, 2008). Furthermore, walking for transport and walking for recreation are influenced by different built environment factors (Saelens & Handy, 2008). While walking for transport is usually associated with density, land use diversity, and street connectivity, recreational walking is related to community neighbourhoods, street-level urban design, aesthetic quality, and accessibility to parks and public transport (Saelens & Handy, 2008; Smith et al., 2017; Yun, 2019).

There is likely to be considerable overlap between walking for transportation and walking for recreation (Forsyth & Krizek, 2010; Gems & Pfister, 2009). For example, people can walk to work because they enjoy it and take it as their daily exercise. This challenge to distinguish types of walking purposes is common in the literature (Saelens & Handy, 2008; Sugiyama, Neuhaus, Cole, Giles-corti, & Owen, 2012). As an example, dog walking was identified as both transport-related walking, recreational walking and even an independent walking category in different studies (Agrawal & Schimek, 2007; Cutt, Knuiman, & Giles-Corti, 2008) (Yang and Diez-Roux, 2012). Some studies classified walking to a fitness facility as recreational walking (Agrawal and Schimek,

2007; Yang and Diez-Roux, 2012). Unlike vehicle-based modes, walking trips are very difficult to define. Walking for transportation often has a defined destination while it is difficult to identify destinations for recreational walking. In travel surveys, people often classify their walking to exercise places or fitness as walking for exercise when it could reasonably be classed as transportation. Another example is a study that has defined walking while visiting historic sites as recreational walking (Tudor-Locke et al., 2007).

2.2.2.4 Other forms of walking

Walking can also be used for purposes that are difficult to classify into either transportation or recreation. For example, people can walk for worship and other religious reasons. One of the most well-known spiritual walking routes is The Camino de Santiago, or the Way of St. James, which was an ancient long pilgrimage trail originating in Santiago de Compostela in medieval times. Nowadays, it has become one of the most popular spiritual journeys in Europe with thousands of participants every year (Slavin, 2003). This pilgrimage develops a deep awareness of the multiple effects of walking among travellers as they progress along the route. Pilgrims report a variety of experiences including using rhythm, `being in the moment', and narrating. Various social borders also establish a space for self-reflection that is both individualistic as well as marked by wider social meanings. Walking is thus simultaneously a bodily, social, and spiritual practice (Slavin, 2003). People can also walk for other social or political purposes including raising money for charity events, marching for election campaigns, or protesting again wars and crimes.

2.2.3 Benefits of walking

Walking has numerous benefits that can be grouped into four main categories (health benefits, social benefits, environmental benefits, and economic benefits) and two levels (individual level and society level) These benefits connect and support each other.

2.2.3.1 Health benefits

2.2.3.1.1 Physical health

At the level of the individual, walking can have numerous benefits for both physical and mental health which are apparent in both the short-term (acute effects of exercise) and long-term (chronic effects) from cumulative adaptations following habitual activity over a period of weeks or months (Barton, Hine, & Pretty, 2009). Walking improves aerobic capacity, trunk muscle endurance, body composition, increases serum high-

density lipoprotein (HDL) cholesterol levels (Parkkari et al., 2000), and flexibility and stability of joints (Ball, Bauman, Leslie, & Owen, 2001). It reduces the risk of cardiovascular disease (Albright & Thompson, 2006), obesity, and type II diabetes (Smith, Wingard, Smith, Kritz-Silverstein, & Barrett-Connor, 2007) by reducing diastolic blood pressure, resting heart rate pressure, waist circumference, body weight, per cent body fat and body mass index (BMI) (Hanson & Jones, 2015; Murtagh et al., 2015). Specifically, walking for at least 30 min per day can reduce the risk of type 2 diabetes by 50% (Hamasaki, 2016). Walking also helps prevent osteoporosis, metabolic disorders (Boardley, Fahlman, Topp, Morgan, & McNevin, 2007), and hypertension (Kokkinos, Narayan, & Papademetriou, 2001).

2.2.3.1.2 Mental health

Although urbanisation has many benefits, it is also associated with increased levels of mental illness, including anxiety disorders and depression (Lederbogen et al., 2011; Peen, Schoevers, Beekman, & Dekker, 2010; Wang, 2004). Many studies have shown that exercises like walking can lead to the release of brain chemicals called endorphins and serotonin - the body's natural happy drugs that improve our mood and relieves stress and depression (Dinas, Koutedakis, & Flouris, 2010; Matzer, Nagele, Lerch, Vajda, & Fazekas, 2018). People who took a 90-minute walk through a natural environment reported lower levels of neural activity in an area of the brain linked to risks for mental illnesses (Bratman, Hamilton, Hahn, Daily, & Gross, 2015). Walking can stimulate other various psychological benefits including positive affect or mood enhancement, more self-confidence and mindfulness (Miller & Krizan, 2016), flexible thinking (Oppezzo & Schwartz, 2014), and better sleep (Wang & Boros, 2021) because it increases blood flow and blood circulation to the brain and body. Walking can reduce feelings of fatigue by up to 65% (Puetz, O'Connor, & Dishman, 2006; Wu, Wang, Liao, Kao, & Huang, 2015). Many studies have reported that walking can improve cognitive health (e.g., mental alertness, improved memory functioning) especially in older people (Bailey, Allen, Herndon, & Demastus, 2018; Roe et al., 2020). Moreover, when walking is combined with social interaction (e.g., walking in groups) and exposure to natural outdoor environments (i.e., green space), the benefits to mental health are further enhanced (Coon et al., 2011; Miller et al., 2019).

2.2.3.1.3 Population health

At the societal level, walking, with all its physical and mental health benefits, has substantial importance to public health since it is the most popular type of moderate-intensity physical activity. The more people engage in walking, the more benefits it can bring to population health. The population health benefits of walking also extend beyond its direct individual benefits in many ways (Lee & Buchner, 2008). As an example, promoting active transport (e.g., walking to work) reduces automobile use and thereby road congestion and air pollution (Xia, Zhang, Crabb, & Shah, 2013). Reducing air pollution is likely to lower rates of asthma and cancer (World Health Organization, 2021). With the considerable health benefits listed, a small shift in the percentage of trips from driving to walking could lead to significant public health benefits.

2.2.3.2 Social benefits

At the individual level, walking offers numerous opportunities for face-to-face social contact and interaction. In the book "Livable Streets", Appleyard found that people who live on streets with light and slow traffic had three times as many friends among neighbours as those on busy roads (Appleyard, Gerson, & Lintell, 1981). Another study by Hart reported the same result that residents of light traffic streets have four times the number of local friends compared with those on heavy traffic streets (Hart, 2008). Importantly, children who walk to school have wider social networks since they can meet with classmates on the way, while children who are driven to school had less opportunity to do so (Living Streets, 2008).

At the societal level, walking is the most accessible physical exercise available to people of all income and social groups, therefore, promoting walking could help reduce health inequalities in society (Marmot, 2013). Research from the University of Cambridge reported that the construction of new walking and cycling routes resulted in more frequent use by a wider range of people resulting in increased physical activity across the population (Le Gouais et al., 2021). Social inclusion, a feature of walking, is also improved by the fact that walking times are similar across all socio-economic groups but other forms of exercise are less likely to be undertaken by disadvantaged groups (Garrard, 2013).

Walking also helps build a sense of community (Wood, Frank, & Giles-Corti, 2010) and fosters community cohesion (Rogers, Gardner, & Carlson, 2014). Walking offers opportunities for social interaction and involvement which bring people together,

strengthen community bonds, and create more social cohesion. A survey of two New Hampshire communities found that walkable areas have high levels of social capital (Rogers et al., 2014). Social capital, as defined by Robert Putnam, refers to "features of social organizations, such as networks, norms and trust that facilitate action and cooperation for mutual benefit" (Putnam, 1993).

Although fear of crime may discourage people from walking vice versa is also true: walking can improve both the perceived and actual levels of safety in communities and contribute to preventing crimes. As in the theory "eyes on the street" by Jane Jacobs (1961), sufficient numbers of people on the street can create a sense of passive surveillance, boosting the perception of safety and confidence.

2.2.3.3 Environmental Benefits

Aside from the modest additional food intake that fuels a walker's incremental expenditure of muscular energy, walking is free of the environmental damage inherent in extracting, transporting, processing, and burning petroleum or other fossil fuels involved in motorised transport, particularly those using combustion engines. At the level of a sustainable society, walking is important in its potential for replacing car trips. By doing so, it can help alleviate the problems of CO2 emissions (Brand et al., 2021) traffic congestion (West of England Partnership, 2006,) noise pollution and waste of landscape for parking and roads. Swapping five small (under 2 km) car trips for 20-minute walks can reduce 86kg of CO2 emissions a year (Potter, 2003). Walking instead of driving helps reduce traffic and noise levels as well as having positive effects on other aspects of the environment and our personal health and well-being. Walking takes far less space of physical road per traveller than automobiles because of the difference not only in the size disparity between individuals walking and vehicles but also in the size of a traffic stream which is inversely proportional to speed (i.e., safe braking distance). Thus, walking can reduce associated environmental damage including loss of open space, conversion of farmland, removal of water and flood drainage, and impacts from creating, installing, and maintaining road surfaces (Komanoff, Roelofs, Orcutt, & Ketcham, 1993). Moreover, the minimum occupied spaces by walkers add little to congestion which has been shown to be harmful to the environment and people's health (Levy, Buonocore, & von Stackelberg, 2010). In terms of land use and urban planning, prioritizing walking in urban development can help prevent urban sprawl thereby reducing greenfield areas into car-dependent urban areas and hence, causing much damage to the environment.

2.2.3.4 Economic benefits

The economic benefits of walking have been documented by several studies across many fields of research including transportation (Button, 2010), medicine and public health (physical activity) (Humphreys & Ruseski, 2011), and economics (Burt & Brewer, 1971).

Transportation economics is the field that has the most economic benefit from walking due to the huge potential of walking in replacing short car trips. At the individual level, walking has always been the most affordable mode of transport, saving a person money spent on a motor vehicle: the buying cost, the cost of learning to drive, registration and insurance cover of the vehicle, fuel cost, servicing and repair costs, tolls, parking costs, and other costs like traffic infringement and parking fines. A study found that car-dependent households spend more than 20% of household expenditure on transportation, while those in areas with more mixed land use and more multi-modal transportation systems spend less than 17% (McCann, 2000).

In the 1950s, transport planning largely focused on increasing travel speeds (Standen, 2018). Planners prioritized faster modes, such as automobiles, over slower but more affordable modes like walking and prioritized higher roadway design speeds and sprawl over compact developments (Litman, 2021). However, this planning exaggerated the benefits and understated the costs of higher speeds (Litman, 2021). As early as the 1960s, evidence showed that prioritising speed above all else is counterproductive, making cities less efficient and liveable and leading people to undertake stressful and unhealthy daily commutes (Standen, 2018). Tranter and May argued that if saving time or increasing speed are the ultimate goals of human travel then investing in walking will be a more effective and useful strategy (Tranter & May, 2006). This is because walking can even be faster than cars under the concept of “effective speed” which is a holistic measure of speed calculated on the amount of time consumed by a particular mode of transport (Tranter & May, 2006). At the level of society, walking substitutes for vehicle travel and reduces the negative impacts of vehicle travel, leading to numerous public cost savings (reduced external costs) including costs for roads, parking, roadway facilities, traffic services, traffic congestion, and traffic crashes in both (Litman, 2017).

In the field of public health and economics, most researchers aim to estimate the monetary benefits of increased walking through various methods. The World Health Organization (WHO) created a tool named the Health Economic Assessment Tool (HEAT) which has become popular in estimating the economic benefits of walking

(Kahlmeier et al., 2014; Kahlmeier, Racioppi, Cavill, Rutter, & Oja, 2010). Research by the RAND Corporation has shown that a 15-minute walk each day could grow the world economy by $100 billion (Hafner et al., 2019). That enormous economic boost would come from three mechanisms: reduced mortality, reduced absenteeism and reduced presenteeism - in simple words, walking keeps more people alive, working and contributing more to the economy (Hafner et al., 2019).

Many studies report walking to have a positive impact on placemaking namely, walking increases retail spending, rental income, land value and economic development. In London, pedestrians spend 40% more each month in neighbourhood shops than motorists (Transport for London, 2013) and improving walking and cycling conditions can increase nearby retail sales by up to 30%, the number of people entering shops by up to 40% and retail rents by 20% (Lawlor, 2013). In New York City, pedestrianization of underused parking areas created an increase of 172% in sales (Garrett-Peltier, 2011). A Hong Kong study also estimated a 17% increase in rental value of retail shops after the pedestrianization of a two-way street (Yiu, 2011). In the US, housing values in nearly all metropolitan areas have been shown to be strongly associated with how walkable the areas are (Cortright, 2009). In particular, a one-point increase in a derived 'Walk Score' is associated with between a USD$500 and USD$3,000 increase in home values (Cortright, 2009).

2.2.4 Walking and measurement

Accurate, valid measures of walking are needed to compare the physical activity behaviours of various populations, to explain the relationships between walking and health or between walking and built environment variables. Key aspects of walking behaviours of interest to researchers are walking time, duration, speed, purpose, leisure, transportation, and work activities. There are several methods have been used. All have different strengths and weaknesses in terms of design, accuracy and implementation.

2.2.4.1 Counting Pedestrians

Pedestrian counts are often used to quantify exposure for safety analysis, rank infrastructure improvements, evaluate the benefits of pedestrian projects, estimate pedestrian volume, and track changes in pedestrian activity over time (Schneider, Arnold, & Ragland, 2009). The method requires standardized definitions of pedestrians and counting procedures. Manual counts are commonly recorded by using data collection sheets or manual 'clickers' in the field (devices that....) or using recorded videos that can

be slowed down or replayed as necessary. Automated counting pedestrians technologies use laser or infrared beam to count pedestrians. In the early age of automated technologies, manual count methods tend to be more accurate than automated count methods since most automated counters cannot distinguish between a person walking, walking a bicycle, or riding a bicycle (Schneider et al., 2009). However, accuracy of manual counting can be affected by human error and depends on the level of motivation and alertness of the observer. Similar to other manual methods, continuous manual counts over lengthy periods are not feasible since most data collectors are subject to fatigue (Schneider et al., 2009)

2.2.4.2 Self-report instruments/ Questionnaires

Self-report is one of the most frequent methods in the estimation of walking and is often used in travel surveys and physical activity surveys. However, self-report instruments that rely on individual recall of behaviour tend to be criticized for their inaccuracy. For example, the International Physical Activity Questionnaire (IPAQ) typically overestimates walking frequency and duration (Lee, Macfarlane, Lam, & Stewart, 2011; Rzewnicki, Auweele, & De Bourdeaudhuij, 2003). Transportation surveys, generally designed to capture motorized trips, tend to underreport short trips, and walking trips in particular (Stopher & Greaves, 2007). Due to the fact that people are often unable to accurately estimate the amount and type of physical activity completed in the surveyed time, self-report measures of physical activity have been reported to have low correlations with objective measures (Banda et al., 2010; Prince et al., 2008; Schuna, Johnson, & Tudor-Locke, 2013). The accuracy of self-report instruments may also be influenced by the length of recalled period since the recall would strongly rely on the recollection of behaviours using episodic memories (Matthews et al., 2018). Short-term recall, therefore, is recommended and has been highlighted to tend to show better agreement with device-based measures (Matthews et al., 2018; Matthiessen et al., 2008; Wollmerstedt et al., 2010)

2.2.4.3 Accelerometers and pedometers

Pedometers and accelerometers are small devices, worn on the body. Pedometers measure steps or distance while accelerometers measure instantaneous accelerations and decelerations for the purpose of estimating energy expenditure or time spent in various intensity categories. These instruments provide more accurate assessments of physical activity intensity and duration than subjective instruments but are limited in identifying

specific types of physical activity such as walking (Bassett Jr, Mahar, Rowe, & Morrow Jr, 2008). Most pedometers undercount steps at slow walking speeds and some accelerometers overestimate the energy cost of walking (Bassett Jr et al., 2008).

2.2.4.4 Methods integrating the Global Positioning System (GPS)

Recent studies have attempted to integrate the use of GPS data into traditional instruments (Rodriguez et al., 2012; Troped et al., 2008). GPS can provide information that is not captured in traditional instruments like walking speed and the accurate location of walking activities. Integrating GPS data into measuring the prevalence of walking helps to identify the origin and destination of walking trips and to also understand the spatial and temporal context in which walking occurs. Troped et al (2008) reported that the addition of GPS to accelerometer monitoring improves physical activity mode classification by studying 10 adults walking under controlled conditions. Rodriguez et al (2012) reported the high accuracy rate of the walking locations obtained by GPS compared with what participants reported in a diary. However, GPS data often have limitations in data completeness. GPS units can have missing data due to several reasons including lost signals inside buildings, signal drop-out, warm start/cold start and power interruptions (Kerr, Duncan, & Schipperjin, 2011; Oliver, Badland, Mavoa, Duncan, & Duncan, 2010). For example, the missing GPS data rate was 92% in the study by Badland et al. (2010) when GPS was only able to capture 2 out of 370 journeys. Therefore biased results may be found in studies using only accelerometers and GPS when missing GPS data are not randomly distributed in time and space (Kang, Moudon, Hurvitz, Reichley, & Saelens, 2013).

In the last decade, the rapid development of technology has led to the tremendous growth of the number of portable and wearable devices such as smartphones, smartwatches, fitness trackers, smart shoes, smart glasses, smart rings, smart helmets, etc. These devices often have built-in sensors such as accelerometers and GPS, providing opportunities to measure walking more precisely and conveniently. These devices can be implemented noninvasively and are capable of continuously measuring with little input from the users (Channa, Popescu, Skibinska, & Burget, 2021). However, the accuracy of walking data may depend on the type and brand of the devices as well as the software (application) being used (Höchsmann et al., 2018).

2.3 Relationship between sociodemographic characteristics and walking

2.3.1 Demographic characteristics

Regarding demographics, gender and age are the most common characteristics that have been included in analysis either as covariates or primary predictors of walking behaviour (Kerr et al., 2016; Shigematsu et al., 2009; Sugiyama et al., 2014; Sundquist et al., 2011; Van Dyck et al., 2012, 2013). Gender and age are usually found to be related to walking (Mendes de Leon et al., 2009a; Mesters, Wahl, & Van Keulen, 2014). In terms of age, the elderly tend to walk fewer trips with shorter distances (Berger, Der, Mutrie, & Hannah, 2005; Mesters et al., 2014; Norman, Bellocco, Vaida, & Wolk, 2002). For walking purposes, older people walk less for transport (Doescher et al., 2014; Turrell, Hewitt, Haynes, Nathan, & Giles-Corti, 2014; Van Dyck et al., 2012) and more for recreation (Van Dyck et al., 2013), which is not unexpected since they are often retired so they mostly engage in a larger share of non-work trips (Yang, Xu, Rodriguez, Michael, & Zhang, 2018). In terms of gender, the results are less consistent across studies. Women are found to walk less than men in some studies (Sundquist et al., 2011; Owen et al., 2007; Forsyth et al., 2009; Doescher et al., 2014). However, Ghani et al. (2016) found that the proportion of recreational walkers was higher for women in all age groups compared with men. Differences in the built environment, as well as social and cultural distinctions between countries, could be the reason for inconsistent results between studies (Ghani et al., 2016).

Walking was also shown to be correlated with, job, household income, marital status, driver status, number of household vehicles, and number of adults and children in the household. (Ory, Towne, Won, Forjuoh, & Lee, 2016; Piirtola et al., 2016; Pucher, Buehler, Merom, & Bauman, 2011). For example, single people often walk less than those who are married (Sobal & Hanson, 2010; Zandieh, Martinez, Flacke, & van Maarseveen, 2017) and those in a household with no vehicles tend to walk more than those who have vehicles (Ministry of Transport NZ, 2019). Overall, walking rates decrease with increasing numbers of cars per household and also with having a driver's license (Clark & Scott, 2013; Paydar & Fard, 2021). Education level is another factor associated with walking behaviour and most studies confirmed people with higher education levels tend to walk more (Mendes de Leon et al., 2009b; Mesters et al., 2014; Piirtola et al., 2016).

In terms of employment status, research in the Czech Republic by Sigmundová et al. (2012) showed that employed men and women walk more than unemployed ones. The

difference can be explained by the fact that employed people use walking as a means of transport to commute to work. However, in some cases, people without a paid job can have more leisure walking than employed ones because they have more free time (Sigmundová et al., 2012).

2.3.2 Socioeconomic status

Many studies have found that lower socioeconomic status is associated with lower overall levels of physical activity (Ford et al., 1991; Gidlow et al., 2006; Mackenbach et al., 2008), especially in the United States (Berry et al., 2010; Keegan et al., 2012; Lopez & Hynes, 2006; Zick et al., 2009). People with lower socioeconomic status tend to walk more for transportation but walk less for recreation than those with higher income (Besser & Dannenberg, 2005; Kruger, Ham, Berrigan, & Ballard-Barbash, 2008; Pucher & Renne, 2003). Those differences in walking result from both individual socioeconomic status itself and environmental factors (Ball et al., 2007; Cerin et al., 2009; Kamphuis et al., 2009). For example, people with lower socioeconomic who either cannot afford private transportation or public transport have fewer alternative modes which lead them to engage in more transportation walking (Lopez & Hynes, 2006). Similarly, in the US, lower levels of recreational walking for lower socioeconomic status groups (Keegan et al., 2012) could be the result of the lack of time and energy due to multiple jobs poor people have to hold for a living. In terms of environmental factors, low SES neighbourhoods often exhibit high-density layouts (Sallis et al., 2011; Zick et al., 2009) primarily due to the affordability of housing, which makes them more friendly for transport walking. However, low socioeconomic status neighbourhoods have poor access to recreational land use such as parks or other green spaces (Abercrombie et al., 2008; Wolch, Wilson, & Fehrenbach, 2005), which results in a low level of recreational walking. At a microscale, poorly maintained streets (Kelly, Schootman, Baker, Barnidge, & Lemes, 2007) and low levels of both traffic and crime safety (Lopez & Hynes, 2006), are often found in low socioeconomic status neighbourhoods. Giles-Corti and Donovan (Giles-Corti & Donovan, 2002) also found that perceived problems, such as traffic poor aesthetic appeal are frequent in low socioeconomic status areas. Those micro characteristics characterized the low socioeconomic status neighbourhoods as less walkable.

2.4 Relationship between urban design and walking

2.4.1 Urban design

2.4.1.1 What is urban design

2.4.1.1.1 Urban design – an ambiguous term

The term ‘urban design’ came into usage in North America in the late 1950s replacing the term ‘civic design’ which is a narrower term that came from the City Beautiful Movement (Carmona & Tiesdell, 2007). Soon afterwards urban design was first recognized as a separate discipline and taught in various universities partially thanks to the gap arising from the split between planning and architecture during the 1960s (Frey, 1999). Since then urban design has been extensively practised and the term has regularly appeared in both educational and professional literature, however, urban design is still an ambiguous term and also an unclear area of activity (Madanipour, 1997). Tibbalds (1984) claimed that there is “no easy, single, agreed definition of urban design”. After reviewing several definitions of urban design, Rowley (1994) concluded that there is considerably less agreement on what urban design is despite the general agreement that it exists and it is impossible to have “a single, succinct, unified and lasting definition” of urban design. The definitions of urban design differed through the different stages of history (Lang, 2000). Elrahman and Asaad (2021) suggested categorising urban design definitions into six groups which are explained in the following sections.

2.4.1.1.2 Urban design as a bridge between planning and architecture

Frey (1999) considered the urban designer as a professional hybrid between urban and regional planners and architects. Gosling and Maitland (1984) suggested urban design lay between the two scales (town planning and architecture) and concerns the physical form of the public realm over a limited physical area. Cunningham (Cunningham, 1972) stated that urban design is similar to architecture due to its physical orientation, but similar to planning in the scale and complexity of the project. Schurch (1999) claimed that urban design belongs “somewhere between these two professions” (architecture and town planning). Levy (2009) and Tibbalds (1988) also shared the idea that urban design is the link between architecture and town planning.

2.4.1.1.3 Urban design as a multidisciplinary process

Urban design was also defined as a multidisciplinary process that confines more than architecture and planning. Tibbalds (1988) believed urban design needs to concern

several aspects such as business, governance, planning and design therefore it is the interface between town planning, architecture and other related professions. According to Erickson and Lloyd (2014), urban design is an economic and political, as well as an aesthetic and functional process. Frey (1999) argued that the urban design process should be an operational component of all disciplines involved in urban development, from urban planning, traffic and infrastructure planning and engineering to urban landscaping and architecture. Schurch (1999) believed architecture, landscape architecture and urban planning, civil engineering, law and real estate, as well as disciplines in the natural and social sciences, are all important components of urban design and give definition to urban design

2.4.1.1.4 Urban design as the relationship between built and unbuilt space

The "Planning Policy Guidance Note 1" by the Department of the Environment (UK) (1992), defines urban design as the complex relationship between all the elements of built and unbuilt space. They explained that it is the relationship between buildings and the streets, squares, parks and waterways and other spaces as well as the relationship between the parts of the city, thus establishing patterns of movement.

2.4.1.1.5 Urban design as the city form and values.

Doug Paterson defined the urban design process as "building the values and ideals of a civilized place into the structure of a city" while Peter Webber described it as "moulding the form of the city through time"(Urban Design Group, 2011). Urban design is concerned with the physical form of cities, buildings and the space between them (Billingham, 1996). Lai (1988) defined urban design as "the composition of architectural form and open space". Lynch (1981) referred to urban design as "the art of creating possibilities for the use, management, and form of settlements".

2.4.1.1.6 Urban design as the process of place-making

Krieger (2006) defined urban design as a place-making process as creating places to serve human purpose has always been central to the design professions and urged urban designers or place-makers to make new places as worthy as their time-honoured predecessors. Commission for Architecture the Built Environment Great Britain) (2000), Prichard and Kenna (2015) both referred to urban design as an art of making places for people.

2.4.1.1.7 Urban design as a way of thinking

Design as a way of thinking emerged in the late 1960s with classic books such as "The Sciences of the Artificial" by cognitive scientist and Nobel Prize laureate, Herbert A. Simon (1969) and "Experiences in Visual Thinking" by Robert H. McKim (1972). Design as a way of thinking also made its way into the architecture field (Lawson, 2006). Sharing that opinion, Marshall (2009) defined urban design as a way of thinking. He believed that urban design is "not about separation and simplification but rather about synthesis".

2.4.1.2 Objectives and goals of urban design

Throughout the literature on urban design, scholars have proposed various objectives and goals of urban design. This section lists some of the most well-recognized examples.

In the book "A theory of good city form", Lynch (1981) defined five performance dimensions of a good city and their sub-principles: (i) vitality (expressed through safe, sustainability and consonant), (ii) sensible (in terms of identity, structure, congruence, transparency and legibility), (iii) fit (resilient and adaptable), (iv) access (to people, human activities, services, material resources, natural environment and information), (v) control (in terms of inhabitants' control, responsibility, and certainty). He also presented two meta criteria efficiency (balancing the benefits and costs) and justice (between persons), which operate on all five dimensions.

Jacobs and Appleyard (1987) proposed seven goals of good urban design: (i) livability: the city should be a place to live in comfort, (ii) identity and control: people feel that a part of the environment belongs to them, (iii) access to opportunity, imagination and joy: the city is a place to have a break from the traditional moulds and enjoy new experiences, (iv) authenticity and meaning: the city should symbolize the moral issues of the society and people should be able to understand their city, (v) community and public life: the city should encourage citizens to participate in the community and public life, (vi) urban self-reliance: the city becomes more sustainable, (vii) an environment for all: everybody has access to all good environments in the city.

Lang (2006) summarised generic objectives of urban designs in the literature: efficiency in handling built environment variables, encouraging economic growth, providing a sense of historic continuity to enhance people's self-image; sustaining the moral and social order of society, and justice for all. He also proposed other goals for urban design including: (i) providing accessible opportunities; (ii) making people

comfortable in engaging with different activities by providing feelings of safety and security; (iii) enhancing the ambience of links (streets, sidewalks, arcades), places (squares, parks, roofs), sense of security and aesthetic qualities; and (iv) protecting and improving terrestrial niches formed by the climate, geology, and flora and fauna of a place.

The United Kingdom Department of Environment, Transport and the Regions (DETR) published a guide on urban design in 2000 which proposed seven objectives of urban design including: (i) character: place with its own identity; (ii) continuity and enclosure: a place where public and private spaces are clearly distinguished; (iii) quality of the public realm: a place with attractive and successful outdoor areas; (iv) ease of movement: a place that is easy to get to and move through; (v) legibility: a place that has a clear image and is easy to understand ; (vi) adaptability: a place that can change easily; (vii) diversity: a place with variety and choice.

2.4.1.3 Scales of urban design

One of the main debates in the urban design field is on the scale of the urban fabric in which urban design operates. Definitions of urban design as explained in the previous sections refer to both the design of cities (macro-scale) as well as the design of specific urban areas such as individual neighbourhoods, streets, or blocks (micro-scale). However, macro- and micro-scales of urban design have very different ranges of issues and considerations. Macro-scale design often focuses on the organization of space and functions, while micro-scale design focuses on architecture, public space, and other detailed elements (Madanipour, 1997). Madanipour (1997) suggested we should acknowledge that urban design deals with urban space at all scales with different concerns and foci because that way of division could help to develop specialisms and a better understanding of the processes and products involved at each level.

In the book “Designing the City: Towards a More Sustainable Urban Form”, Frey (1999) presented three scales of urban design: city, the city district, and individual spaces. Bacon (1976) suggested that urban design can have six scales: state/region, large city, normal city, sections, buildings, and details. Likewise, Schurch (1999) concluded that urban design practice can occur at five project scales including individual sites, districts or neighbourhoods, streets and other corridors, an entire city, and a region. Urban design practice can be grouped into any one or possibly a combination of these five scales. Schurch (1999) believed that urban design activity at any scale needs to consider the

context of the other scales, therefore he used the term “thresholds of scale”. For example, designing streets or individual building sites would require consideration of the context of the surrounding neighbourhood or district.

2.4.2 Walkability

2.4.2.1 What is walkability

Although urban design and transportation research has been interested in the role of walking in urban environments for many years (Frank & Pivo, 1994; Gehl, 1987; Handy, 1996), the term “walkability” only appeared in literature in the early 2000s when researchers began to examine how neighbourhood designs influenced travel behaviours and physical activity (Hajna, Ross, Griffin, & Dasgupta, 2017). Today, due to the increasing demand for sustainable urban development (Steven Spoon, 2005), the term, along with multiple operational definitions and measurement tools has been widely adopted by the academic community, working professionals, and the general public. However, there are numerous conflicting definitions (Forsyth, 2015) and the core concepts behind it remain elusive (Dovey & Pafka, 2019).

Most of the walkability literature provides a host of various definitions and variables that are hypothesized to promote walking behaviours. King et al. defined walkability as “the neighbourhood’s ability to support walking as a means of purposeful transportation or utilitarian walking” (King et al., 2011). Leslie and colleagues defined walkability as “the extent to which characteristics of the built environment and land-use may or may not be conducive to residents in the area walking for either leisure, exercise or recreation, to access services, or to travel to work” (Leslie et al., 2007). Other definitions include “a neighbourhood’s capacity to support lifestyle physical activity” (Carr, Dunsiger, & Marcus, 2011), “the extent to which the built environment is walking-friendly” (Reyer, Fina, Siedentop, & Schlicht, 2014), “walkability reflects the built environments’ convenience for walking and is expressed as an index based on three key components; street connectivity, residential density, and land use mix diversity” (Van Holle et al., 2014). Each of these definitions is correct in its own way, but none is broad enough to encompass all relevant environmental features that may encourage walking.

The “walkability” term was criticized as a misleading term and “not neutral enough” because it focuses only on a single type of physical activity and assumes that there is a universal association between the built environment and walking (Hajna et al., 2017). Hajna et al. (2017) argued that the term narrows understanding of the role of

neighbourhoods on human health by linking it just to walking and underrating the potential influence on other physical activities such as jogging, running, and cycling. They also raised another problem that the term "walkability" only expresses the universal association between environments and walking but ignores the complexities of this relationship in different settings and contexts. They suggested using a new term named "neighbourhood physical activity environments" to ensure including other physical activities. Sharing the same opinion, Gauvin et al. (2005) were concerned that walkability may be a misnomer because "walkable" environments can sustain a variety of forms of human-powered activity not only walking. They proposed the concept of "Neighbourhood Active Living Potential (NALP)" to extend the concept of walkability beyond walking. Both concepts by Gauvin et al. (2005) and Hajna et al. (2017) are successful in extending the potential effects of environments to all physical activity and avoiding implying the causal association exists between walking and environments, but the geographic boundaries have been restricted to the neighbourhood only in both concepts.

2.4.3 Walkability indicators

There are hundreds of environmental variables that researchers have tested to operationalize the concept of walkability and this section will summarise some most significant ones. Frank and Pivo (1994) developed a walkability index that comprised measures of mixed land use and net residential density. The most well-known variables to measure walkability are the 3Ds (density, diversity, and design) first used by Cervero and Kockelman (1996), which were expanded to 5Ds by including "destination accessibility" and "distance to transit" (Ewing & Cervero, 2010). The availability of GIS enabled the creation of observation-specific buffers, connectivity (e.g., intersection density), and site design (e.g., retail floor space ratio) measures. Spoon (2005) synthesized 11 variables of walkability from literature into three main groups: "essential", "encourage", and "extra" characteristics. "Essential" variables included mixed land use, accessibility/convenience, presence of pedestrian facilities, and high connectivity. "Encouraged" variables included street pattern, density, aesthetics, presence of parks, plazas, and open spaces, and traffic calming/street speeds, while street orientation and access to transit were variables in the "Extra" group (Steven Spoon, 2005). In 2006, Krambeck proposed "The global walkability index" and tested it in various cities in over the world. The index consisted of three components: "Safety and security", "Convenience

and attractiveness" and "Policy support" (Krambeck & Shah, 2006). Lo conducted a review of the literature related to walkability and summarised 12 characteristics that encompassed walkability including "the presence of continuous and well-maintained sidewalks", "universal access characteristics", "path directness and street network connectivity", "the safety of at-grade crossing treatments", "absence of heavy and high-speed traffic", "pedestrian separation or buffering from traffic", "land-use density", "building and land-use diversity or mix", "street trees and landscaping", "visual interest and sense of place as defined under local conditions" and "perceived or actual security" (Lo, 2009). Glazier et al. (2014) used four features to define walkability, population density, residential density, number of retail and services, and street connectivity (Glazier et al., 2014). Forsyth (2015) identified nine themes of walkability and grouped them into four sets. The first set of themes included the required environmental conditions for walkability that are "traversable", "compact", "safe", and "physically enticing" (Forsyth, 2015). The next set of themes is the outcomes that come from walkability, including "lively and sociable", "exercise-inducing" and "sustainable transport" (Forsyth, 2015). The final set named "proxies" is comprised of "multidimensional" and "holistic" (Forsyth, 2015).

2.4.4 Urban design and walking

2.4.4.1 Macro-scale urban design and walking

Understanding how the built environment and urban design elements may affect walking is a rapidly expanding area of inquiry, predominantly arising from three fields: transportation research, urban planning, and public health. However, this section will not focus on discussing the relationships between urban design and walking in these three fields. Instead, the section will review the literature from the spatial scales approach since the macroscale and microscale studies have completely different sets of urban design elements that are likely to have different impacts on walking behaviours.

At the macro-scale, the most well-known built environment variables are the 3Ds (density, diversity, and design) first used by Cervero and Kockelman (Cervero & Kockelman, 1996), which were later expanded to 5Ds by including destination accessibility, distance to transit (Ewing & Cervero, 2010).

2.4.4.1.1 Density

'Density' or compactness in the urban context is defined as the number of 'things' or the amount of "activity" per unit of land area (Handy, Boarnet, Ewing, &

Killingsworth, 2002b). In an urban environment, urban density includes the density of schools, jobs, and hospitals or the density of services such as retail, transit, and recreational facilities. Density is an essential measure of the association between environment and walking because high density often means more compact land development, shorter travel distances (Frank, 2000), and decreased dependence on motorized transportation (Cervero & Kockelman, 1996). Furthermore, the ease of collection, computation and interpretation make density the most measured. Population density (number of people per unit area), residential density (number of dwelling units per unit area), and household density (number of households per unit area) are commonly used measures of density (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009). Population density and residential density often affect walkability positively since densely populated an area often come with higher levels of land use mix, and more commercial and recreational areas (Brennan Ramirez et al., 2006; Brownson et al., 2009; Saelens, Sallis, & Frank, 2003b; Tomalty & Haider, 2009). Residential density is often recommended to be used, especially when measuring on larger geographic scales or in cases of insufficient data because it excludes other non-residential land uses and serves as a proxy for other urban form factors (Saelens et al., 2003b). Some other densities include employment density (number of employees per unit area), retail density (number of retail locations in a given area), building density (proportion of the area of land which is occupied by the building) and floor area ratio (the ratio of the total area of the building to the area of the land). Higher levels of employment, retail locations and larger retail floor area of an area are expected to affect walkability positively since there would be a greater number of destinations within short distances in the local area.

Many studies have found that densities are significantly associated with the probability of walking. Analysing the 1990 Nationwide Survey, Dunphy and Fisher (Dunphy & Fisher, 1996) were able to demonstrate that walking trips became more frequent at higher densities, growing from about 0.3 daily walking trips to 1.5 trips by the average resident within an increase from 4,500 to 40,000 residents per square mile. An analysis of the complementary influences of density and land-use mix on the choice of single-occupant vehicle, transit, and walking by Frank and Pivo (1994) suggested that the proportion of walking work trips increased at higher employment densities and higher population densities. Findings suggest a minimum of 13 residents per acre for changes in mode choice from SOV to walking to occur. In a comparative study, Kitamura et al. (1997) analysed travel behaviours in the San Francisco Bay Area in five neighbourhoods

matched by median income, controlling for household size, car ownership, and income. Results showed a greater share of walking trips among residents at higher densities. On a nationwide scale, studying the 1995 Nationwide Survey, Ross and Dunning (2018) concluded that walk-mode share increased at higher population densities.

The significance of density in explaining walking rates to transit is consistent with the findings of studies related to the choice to walk for other utilitarian or recreational purposes. In an analysis of three California metropolitan areas, in which transit commute shares and transit mode of access were regressed on variables such as employment density and land-use mix variables, Cervero (1994) found that at higher density work settings rail users had higher shares of midday walk trips. In a study that investigated walk trips for riders using the public transit BART system, Loutzenheiser (1997) found that the variation in walk-mode share by residents per station is related to the population density around stations. In addition, in the same study parking capacity was found to be negatively correlated with walk-mode shares.

In their pivotal study, Newman and Kenworthy (1991) showed the association between high fuel consumption and low urban density in North American and Australian cities in comparison to more energy-efficient European cities with higher density. Based on their findings the authors concluded that due to the multiplicative effect of low density on travel distances, walking as a transit access/egress mode became impossible since a higher per cent of the population lived outside of walking distance thresholds. Besser and Dannenberg (2005) used the 2001 National Household Travel Survey (NHTS) to assess Americans' daily activity levels based on the walk-mode choice to transit. All walking trip times to/from transit for one day were recorded to calculate the total walking time for transit. The findings of this study indicated that, in higher-density urban areas, people had higher mean total walking times compared with people living in less dense areas.

A considerable number of studies have shown the association between density and walking. However, there is considerable debate over whether the changes in walking are the result of density itself or density acting as a proxy for other attributes, (e.g., household characteristics, vehicle ownership and parking supply).

2.4.4.1.2 Diversity

Diversity refers to the spatial arrangement of land use that encourages mix-use, influencing the influences the distance and mode of travel (Feng, Glass, Curriero, Stewart, & Schwartz, 2010). Studies regarding how walking is affected by land-use diversity have

verified that dense land-use patterns play a vital role in encouraging walking trips. Well-mixed land use offers a broad range of services in an area, increasing the proximity between destinations, thereby shortening trip distances and promoting active transport (Cervero & Kockelman, 1996; Frank, 2000). Land use diversity also offers local employment opportunities and adds visual interest for pedestrians (Forsyth, Schmitz, Oakes, Zimmerman, & Koepp, 2006). Diversity is most frequently measured by the entropy index representing proportions of lands for different uses (residential, commercial, office, and institutional uses) (Feng et al., 2010). When data is not available or insufficient to use this entropy index, simpler approaches will be used to assess the land use mix, such as surveying the number of destinations in the areas. Another way is measuring diversity by the number of non-residential uses or retail floor area ratio assessed through built environment audits.

Studies regarding how walking is affected by land-use diversity have verified that dense land-use patterns play a vital role in encouraging walking trips. Among elements of urban design, land use mix is the most frequently assessed built environment factor of walking or physical activity in general (Brownson et al., 2009). However, the results of the relationship between walking and land use mix are inconsistent. Several studies show that mixed-use supports walking (Christiansen et al., 2016; Eriksson, Arvidsson, Gebel, Ohlsson, & Sundquist, 2012; Frank, Schmid, Sallis, Chapman, & Saelens, 2005) whereas other studies suggest that land use mix is insignificantly associated with walking (Clark, Scott, & Yiannakoulias, 2014; Forsyth, Hearst, Michael Oakes, & H. Schmitz, 2008; McCormack et al., 2012). The considerable variation in the results comes from the difference in the theoretical and methodological approach of the research design. For example, there is considerable variation between researchers on the definition and measurement of land use mix and walkability. Handy et al (2002a) defined land use mix as the relative proximity of different land uses including office, retail/commercial, residential and public space. Ewing and Cervero (2010) considered land use mix as being the number and relative size of land use types in an area. The measurement of land use mix in these two studies is distance-based accessibility. From another standpoint, land use is defined as the level of integration among different land use types in an area mix (Saelens et al., 2003b). Saelens et al. (2003b) also described walking as an activity that can be done for exercise, recreation, leisure, occupational purposes or transportation. Based on this perspective, Saelens and Handy (2008) conducted a meta-review of prior reviews and original studies on the topic of walking and the built environment. Their

review confirmed the positive association between walking for transportation and mixed-use density. However, their review indicated that this link was less clear for recreational walking in more recent studies. In the same year 2008, a study by Forsyth et al. has surprisingly contrasting results (Forsyth et al., 2008). Forsyth and colleagues provided more comprehensive measurements of these built environment elements (including mixed-use) at multi scales which goes beyond most earlier work by Cervero and Kockelman (1996) and Frank and Pivo (1994). They indicated that only 2 of 44 mixed-use measures were associated with walking. The association of traditional measures such as destination proximities and entropy scores to walking even were insignificant. The expected positive association between the built environment measures and overall physical activity was not observed by Forsyth et al (2008). The difference in the conclusions of this research suggests a need to better understand how the composition of different land use types and the measurement of land use diversity affects the association between urban design and walking.

2.4.4.1.3 Design (Connectivity)

Connectivity refers to the degree to which roads, sidewalks, pedestrian walkways, and trails are connected (Marshall, 2004). High connectivity increases the ease of travel between places by reducing trip distance and providing multiple alternate routes, which in turn encourages walking (Saelens, Sallis, Black, & Chen, 2003a). If streets cross each other at right angles (i.e., a grid pattern street layout), they will create a high connectivity model with small blocks and many intersections. In contrast, low connectivity areas are represented by fewer intersections and blocks but a high number of dead-end streets and few route choices (Feng et al., 2010; Handy, Paterson, & Butler, 2003). Measures of connectivity are basically related to the layout of blocks (size, length) and streets intersection (intersection types (three-ways, four-ways), intersection density, intersection ratio) (Feng et al., 2010) or more complex network variables such as the network index (km of links divided by area), beta index (the number of links divided by the number of nodes) or gamma index (the number of observed links and the number of possible links) (Rodrigue, 2020).

Walking is influenced by street connectivity both directly and indirectly (Berrigan, Pickle, & Dill, 2010). The ease of walking from place to place and the aesthetic correlates of more connected networks are the direct effects, while the associations between destinations and connectivity are indirect effects (Berrigan et al., 2010). Street networks

with high connectivity promote walking by providing more route options and shorter and more direct routes (Berrigan et al., 2010; Handy et al., 2003; Saelens et al., 2003b). Positive associations between walking for transport and street connectivity are reported in about 60% of studies (Sugiyama et al., 2012). However, the relationship between street connectivity and walking is partly moderated by the utilitarian destinations located in the study area (Koohsari, Sugiyama, Lamb, Villanueva, & Owen, 2014). Several studies have reported people are more likely to walk for transport if there are destinations in their area (Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Saelens & Handy, 2008; Sugiyama et al., 2012). Also, negative associations of street connectivity with total walking or walking for leisure have been found in some studies (Gómez et al., 2010; Lovasi et al., 2008) (Lovasi et al., 2008) (Ball et al., 2007). One reason may be that neighbourhoods with higher street connectivity may have higher traffic that discourages walking (Jia et al., 2021).

2.4.4.2 Microscale urban design and walking

2.4.4.2.1 Pedestrian Infrastructure

Pedestrian infrastructure, a microscale characteristic of the built environment, plays a key role in encouraging walking, as documented in the literature. There are main features: *1. Sidewalk; 2. Street crossing amenities and support; 3. Street lighting.*

The presence, continuity, and maintenance of the sidewalk along with design features of the sidewalk, such as width, surface, and materials are important. Many studies have found significant associations between walking and different sidewalk variables, including the presence of a sidewalk (Chaudhury, Mahmood, Michael, Campo, & Hay, 2012; Gallagher, Clarke, & Gretebeck, 2014; Sallis et al., 2015), design elements of sidewalk such as buffer, curbs, and benches (Sallis et al., 2015), and width and continuity of sidewalk (Chaudhury et al., 2012). Analyzing data from 11 countries, Sallis et al. (2009) found that the presence of sidewalks was the most strongly associated with physical activity compared with other built environment characteristics. In qualitative studies, poor sidewalk quality and design were found to discourage walking with common problems including uneven or slippery surfaces, cracks, potholes and other obstructions, pools of rainwater, delayed snow and ice clearance (Buman et al., 2013; Chaudhury et al., 2012; Chippendale & Boltz, 2015), and lack of suitable sidewalk infrastructure for mobility disability (Buman et al., 2013). In contrast, several design elements are facilitators of walking including seating or benches, railings, handrails, ramps, and safe

stairs (Chaudhury et al., 2012; Chippendale & Boltz, 2015). However, some studies found no association between sidewalk availability and walking (Rodriguez, Aytur, Forsyth, Oakes, & Clifton, 2008; Rutt & Coleman, 2005). The reason might be that they only focused on the availability of the sidewalk but ignored other micro-features of the sidewalk mentioned above.

The presence of street crossings encourages physical activity including walking (Cain et al., 2014; Sallis et al., 2015). Crossing characteristics, such as crosswalk markings, crossing signals (e.g., walk, countdown, and/or audible signals), the width of crossings, and crossing protections (e.g., protected refuge islands, curb extensions) were found to be associated with walking (Cain et al., 2014). Sallis and colleagues (2015) also identified a significant relationship between active transport (walking for transportation) and the presence of microscale crossing features. In qualitative studies, the presence of safe crosswalks was also referred to as the facilitator of physical activity (Buman et al., 2013) while the absence of crossings, the lack of, or poor design and maintenance of crossing amenities (e.g., inoperable or broken signals), were reported to discourage the engagement in walking (Buman et al., 2013; Cain et al., 2014; Chaudhury et al., 2012; Chippendale & Boltz, 2015; Sallis et al., 2015).

Streetlights play a critical role in providing feelings of safety and security during dawn, dusk, or night-time (Sallis et al., 2015). Sallis and colleagues (2015) found significant associations between walking for transport and the presence of streetlights. The presence of lighting was also found to encourage walking by reducing fears of falling and increasing the visibility of obstructions on the sidewalk (Chaudhury et al., 2012; Chippendale & Boltz, 2015). However, Buman et al. (Buman et al., 2013) did not identify lighting conditions as an important facilitator of physical activity. The reason might be that people may simply avoid going out in the dark, and well-lit streets might not be a powerful enough facilitator to encourage them to walk at night (Buman et al., 2013).

2.4.4.2.2 Safety

Perceptions of safety are a common microscale feature that influences walking behaviours with two specific aspects: traffic safety and crime safety.

2.4.4.2.2.1 Traffic safety

Perceptions of traffic safety were found to be correlated with both walking to employment and total weekly walking. Safety concerns were associated with reduced

walking (Maisel, 2016). Oyeyemi et (2012) also found that physical activity was related to the individual's perception of traffic safety. In qualitative studies, traffic safety concerns that discourage walking have been highlighted such as personal safety fears (e.g., being hit by a vehicle), unsafe intersections and crosswalks, busy streets with high traffic volume and speed, aggressive or ignorant drivers, poor visibility (Buman et al., 2013; Chaudhury et al., 2012), getting hit by cyclists, skateboarders, and other forms of non-motorized transport (Chippendale & Boltz, 2015). Traffic safety can also be boosted by pedestrian infrastructure including: elevators to access the subway, benches for resting, fences or railings for support, signal crossings (timed crossings that indicate the amount of time remaining to cross, and flashing crosswalks that calm traffic) (Chaudhury et al., 2012; Chippendale & Boltz, 2015). From a social environment perspective, communication from drivers that it was safe to cross or the presence of crossing guards and other officials was found to increase the perception of traffic safety while walking (Chippendale & Boltz, 2015).

2.4.4.2.2.2 Crime safety

The perceived influence of crime on walking has been extensively studied. There are many studies that associate crime safety to walking rates (Burgoyne, Woods, Coleman, & Perry, 2008; Caperchoine, Mummery, & Joyner, 2009; Van Cauwenberg et al., 2012). Doyle et al. (2006) reported that people who live in an area that has lower crime rates tend to walk more. Maisel (2016) found that people with more positive perceptions of crime safety reported more walking. Gallagher and colleagues (Gallagher et al., 2014) also confirmed walking duration was significantly influenced by the perception of crime. Notably, the perception of safety from crime often was of greater concern among women than men (Eriksson & Emmelin, 2013) and low-socioeconomic status neighbourhoods compared with high-socioeconomic areas (Cassou et al., 2011). Perceptions of crime safety is negatively influenced by several factors such as the presence of gangs and drug dealing (Burgoyne et al., 2008; Caperchoine et al., 2009; Zieff, Guedes, & Eyler, 2012), loitering, explicit sexual behaviours (Yen, Scherzer, Cubbin, Gonzalez, & Winkleby, 2007), vandalism (Mahmood et al., 2012), lack of cleanliness (Burgoyne et al., 2008; Stathi et al., 2012; Zieff et al., 2012) and illegally parked cars on sidewalks (Stathi et al., 2012). Conversely, increased perceptions of crime safety are supported by the presence of other people (Chippendale & Boltz, 2015), the

presence of police (Stathi et al., 2012; Yen et al., 2007; Zieff et al., 2012) and knowing neighbours (Walker & Hiller, 2007).

2.4.4.2.3 Aesthetics

Aesthetics are features of the built environment that are perceptually pleasing or attractive. People are encouraged to be active within public environments that are aesthetically pleasing (Gallagher et al., 2010; Ivory et al., 2015; Stathi et al., 2012). Colourful and peaceful areas with trees, flowers well maintained green spaces were reported facilitators of neighbourhood walking (Buman et al., 2013; Chippendale & Boltz, 2015; Gallagher et al., 2010). Water elements such as water views, beaches [47], rivers [13] and waterfalls [37] were also reported as enablers for walking in public areas (Ivory et al., 2015; Lockett, Willis, & Edwards, 2005; Montemurro et al., 2011). Human-made elements, such as appealing architecture, historic buildings and monuments, public art, presence of different types of urban furniture encouraged participants to walk (Gallagher et al., 2010; Van Cauwenberg et al., 2012). The presence of shops was also a feature that encouraged walking, not only for convenience but also by making streets more attractive through well-presented shopfronts and windows(Van Cauwenberg et al., 2012).

In contrast, abandoned or vacant houses and lots, overgrown vegetation like bushes and shrubs, and trash/litter were the most common unesthetic elements that discourage neighbourhood walking (Gallagher et al., 2010; Salvo, Lashewicz, Doyle-Baker, & McCormack, 2018).

Aesthetics are not always influential as is the case when walking for transport. Maisel (2016) found that aesthetics were significantly correlated with recreational walking, however, they were unrelated to job or transport walking. Similarly, Sallis et al (2015) concluded that transport walking was not associated with both aesthetics and social characteristics. It can be explained as time and distance are more important to walking for transport than walking for recreation where experience is essential. People expressed their willingness to take longer routes if they are more appealing (Eyler et al., 1998; Strath, Isaacs, & Greenwald, 2007)

2.4.4.2.4 Urban design qualities

Ewing et al. (2006) proposed a conceptual framework explaining the process of how physical features of the environment are perceived. The physical features of urban spaces will create the urban design qualities which are perceived differently by different

users and lead to their own perceptions and reactions (Parashar & Bnayan, 2020). Ewing et al. (2006) described those urban design qualities as below:

- **Imageability** is the quality of a place that leaves distinct, recognisable, and memorable images in the minds of people. Features of high imageability spaces include physical elements that can capture, create and evoke emotions. The elements measured are the number of people on the street, the proportion of historic buildings, courtyards, plazas, parks and outdoor dining areas.
- **Enclosure** is the degree to which streets have a room-like feeling, defined by vertical elements such as buildings, walls, trees, and other vertical elements. The tool records the number of long sight lines, the proportion of street walls and the proportion of sky view to determine the enclosure level.
- **Human scale** is the proportion of physical elements' size, texture, and articulation that match the human form and correspond to people's walking speed. The elements that influence the quality of human scale quality include the height and length of buildings, the proportion of windows, on-street furniture, and small planter-boxes.
- **Transparency** refers to the level of human activity that can be seen and perceived beyond the edge of the street or public space. The proportion of windows per..., street walls and the level of active use of the space are factors that affect the transparency of a street.
- **Complexity** is the level of the visual richness of a street. The variety of physical elements, specifically the numbers and types of buildings, ornaments, landscape features, and human activity, contribute to the complexity of a street.

2.4.5 Methods for measuring urban design

2.4.5.1 Types of measures

Measuring built environment data is important to understand its impacts on physical activity (Brownson et al., 2009). There are two types (perceived and objective) with two scales (micro and macro) of measures that have been commonly used to operationalize urban design characteristics in the literature. Perceived characteristics are residents' perceptions of the urban design obtained by telephone interviews or self-administered questionnaires. Alternatively, objective characteristics are collected using systematic observational methods (audits) or geographic information systems (GIS). Characteristics

in both two types of measures are at either microscale (street-level) or macroscale (neighbourhood level).

2.4.5.1.1 Objective macroscale measures

The objective macroscale measures typically involve collecting and analyzing data from geographic information systems (GIS). In the macro-scale, the most well-known built environment variables are the 3Ds (density, diversity, and design) first used by Cervero and Kockelman (Cervero & Kockelman, 1996), which were expanded to 5DS by including destination accessibility and distance to transit (Ewing & Cervero, 2010). Due to the objectiveness and the availability of data sources, the macro-scale studies together with the well-known D variables are dominant in the literature on the study of urban environments. Despite their usefulness and popularity, some argue that the D variables insufficiently represent the urban environment in terms of physical activity friendliness (Sallis et al., 2011). One of the reasons for this is the challenge of operationalizing the D variables. While the measurement of Density and Diversity is often straightforward, quantifying the remaining D variable, Design, is a challenge (Ewing, Hajrasouliha, Neckerman, Purciel-Hill, & Greene, 2015). The gross characteristics of street networks such as intersection density and block size, which are mostly used to calculate the Design variable, may not affect the experience of people using the street as much as the micro-features of the streets (Ewing et al., 2015). Another problem is that obtaining GIS data can be challenging and costly (Brownson et al., 2009) because they may be insufficient, inconsistent, not available, or administratively burdensome to use, especially in low- and middle-income countries (Porter, Kirtland, Williams, Neet, & Ainsworth, 2004; Salvo, Reis, Sarmiento, & Pratt, 2014).

2.4.5.1.2 Objective microscale measures

Objective microscale measures are commonly systematic observational measures using audit tools. Audit tools allow the systematic observation of both the presence and qualities of urban design features (Brownson et al., 2009). The most visible challenges of this method are time-consuming and labour-intensive due to the involvement of numerous procedures such as selecting sites, defining and sampling segments within sites, training, and monitoring auditors, and collecting and entering data (Brownson et al., 2009).

2.4.5.1.3 Perceived measures

Perceived measures ask residents about their perceptions of surrounding urban design using interview or self-administered questionnaires (Brownson et al., 2009). At

the macroscale level, perceived measures often include distance, access, and/or proximity to non-residential uses and perceived street connectivity. At the microscale level, they collect perceptions of pedestrian infrastructure, aesthetics, and traffic safety (Toker, 2015). Although perceived measures of urban design are relatively easy to collect, these measures often face issues of measurement reliability (Kim, Park, & Lee, 2014). Lin & Moudon (2010) have also suggested that objective measures show a stronger association with physical activity than subjective ones.

2.4.5.2 Measurement tools

Because researchers have developed numerous instruments and protocols to measure the built environment in general and urban design in particular and tools vary significantly in what features they measure and how they measure them. Table 2-1 summarises the most well-recognized measure tools that have been frequently used and cited in various studies. Tools are listed in an order based on their types of measure (perceived, observational, GIS) and their constructed year. The table provides other descriptions of the tools including name, authors, the published articles or protocol along with corresponding journals, number of items/variables/indices, methods of collecting data, and the test location.

Table 2-1 Urban design measurement tools.

Tool name	Authors (year)	Article and journal	No of elements	Type of measure	Mode of data collection	Test location
San Diego scales of home & neighbourhood environments and convenient facilities	Sallis, J. F., Johnson, M. F., Calfas, K. J., Caparosa, S., & Nichols, J. F. (1997)	Assessing perceived physical environmental variables that may influence physical activity. *Research quarterly for exercise and sport*. 68(4), 345-351	43	Perceived	Self-administered	U.S.
Neighbourhood Quality Index	Yang, M. J., Yang, M. S., Shih, C. H., & Kawachi, I. (2002)	Development and validation of an instrument to measure perceived neighbourhood quality in Taiwan. *Journal of Epidemiology & Community Health*, 56(7), 492-496.	15	Perceived	Self-administered	Taiwan
Perceptions of Environmental Support Questionnaire	Kirtland, K.A., Porter, D.E., Addy, C.L., Neet, M.J., Williams, J.E., Sharpe, P.A., Neff, L.J., Kimsey Jr, C.D. & Ainsworth, B.E (2003)	Environmental measures of physical activity supports perception versus reality. *American journal of preventive medicine*, 24(4), 323-331.	26	Perceived	Interview by telephone	U.S.
Neighbourhood Environment Walkability	Saelens, B. E., Sallis, J. F., Black, J. B., &	Neighbourhood-based differences in physical activity: an environment scale evaluation.	68	Perceived	Self-administered	U.S.

Tool name	Authors (year)	Article and journal	No of elements	Type of measure	Mode of data collection	Test location
Scale (NEWS)	Chen, D. (2003a)	American journal of public health, 93(9), 1552-1558.				
Perceived walking environment	Humpel, N., Marshall, A. L., Leslie, E., Bauman, A., & Owen, N. (2004)	Changes in neighbourhood walking are related to changes in perceptions of environmental attributes. *Annals of Behavioural Medicine*, 27(1), 60-67.	8	Perceived	Interview by telephone	Australia
Neighbourhood walking survey	Li, F., Fisher, K. J., & Brownson, R. C. (2005)	A multilevel analysis of change in neighbourhood walking activity in older adults. *Journal of aging and physical activity*, 13(2), 145-159.	15	Perceived	Interview by telephone	U.S.
Physical Activity Neighbourhood Environment Survey (PANES)	Alexander, A., Bergman, P., Hagströmer, M., & Sjöström, M. (2006)	IPAQ environmental module; reliability testing. *Journal of Public Health*, 14(2), 76-80.	17	Perceived	Self-administered	Sweden
Neighbourhood Physical Activity Questionnaire (NPAQ)	Giles-Corti, B., Timperio, A., Cutt, H., Pikora, T.J., Bull, F.C., Knuiman, M., Bulsara, M., Van Niel, K. and Shilton, T. (2006)	Development of a reliable measure of walking within and outside the local neighbourhood: RESIDE's Neighbourhood Physical Activity Questionnaire. *Preventive medicine*, 42(6), 455-459.	N/A	Perceived	Self-administered	Australia
Systematic Pedestrian and Cycling Environmental Scan (SPACES) Instrument	Pikora, T. J., Bull, F. C., Jamrozik, K., Knuiman, M., Giles-Corti, B., & Donovan, R. J. (2002)	Developing a reliable audit instrument to measure the physical environment for physical activity. *American journal of preventive medicine*, 23(3), 187-194.	51	Observational	Paper form	Australia
Walking Suitability Assessment Form	Emery, J., Crump, C., & Bors, P. (2003).	Reliability and validity of two instruments designed to assess the walking and bicycling suitability of sidewalks and roads. *American Journal of Health Promotion*, 18(1), 38-46.	15	Observational	Paper form	U.S.
Senior Walking Environmental Audit Tool (SWEAT)	Cunningham, G. O., Michael, Y. L., Farquhar, S. A., & Lapidus, J. (2005)	Developing a reliable senior walking environmental assessment tool. *American journal of preventive medicine*, 29(3), 215-217.	188	Observational	Paper form	U.S.
Irvine–Minnesota Inventory	Day, K., Boarnet, M., Alfonzo, M., & Forsyth, A. (2006)	The Irvine–Minnesota inventory to measure built environments: development. *American journal of preventive medicine*, 30(2), 144-152.	176	Observational	Tablet PC and paper form	U.S.
Measure Urban Design Qualities	Ewing, R., Handy, S., Brownson, R. C., Clemente, O., & Winston, E. (2006)	Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health*, 3(s1), S223-S240.	27	Observational	Paper form	U.S.
Active Neighbourhood Checklist	Hoehner, C. M., Ivy, A., Ramirez, L. K. B., Handy, S., & Brownson, R. C. (2007)	Active neighbourhood checklist: a user-friendly and reliable tool for assessing activity friendliness. *American Journal of Health Promotion*, 21(6), 534-537.	57	Observational	Paper form	U.S.

Tool name	Authors (year)	Article and journal	No of elements	Type of measure	Mode of data collection	Test location
Pedestrian Environment Data Scan (PEDS)	Clifton, K. J., Smith, A. D. L., & Rodriguez, D. (2007)	The development and testing of an audit for the pedestrian environment. *Landscape and urban planning*, 80(1-2), 95-110.	36	Observational	PDA and paper form	U.S.
Measures of environmental characteristics	Suminski, R. R., Heinrich, K. M., Poston, W. S., Hyder, M., & Pyle, S. (2008)	Characteristics of urban sidewalks/streets and objectively measured physical activity. *Journal of Urban Health*, 85(2), 178-190.	14	Observational	PDA and paper form	U.S.
Walkability Index (WAI)	Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010)	The development of a walkability index: application to the Neighbourhood Quality of Life Study. *British journal of sports medicine*, 44(13), 924-933.	4	GIS	Spatial data sources	U.S.
The Pedestrian Index of the Environment (PIE)	Clifton, K. J., Singleton, P. A., Muhs, C. D., & Schneider, R. J. (2016)	Representing pedestrian activity in travel demand models: Framework and application. *Journal of transport geography*, 52, 111-122.	5	GIS	Spatial data sources	U.S.
The Pedestrian Potential Index (PPI)	Robitaille, É (Institut national de santé publique du Québec (INSPQ)) (2009).	Indicateurs géographiques de l'environnement bâti et de l'environnement des services influant sur l'activité physique, l'alimentation et le poids corporel	4	GIS	Spatial data sources	Canada
The Neighbourhood Destination Accessibility Index (NDAI)	Witten, K., Pearce, J., & Day, P. (2011)	Neighbourhood Destination Accessibility Index: a GIS tool for measuring infrastructure support for neighbourhood physical activity. *Environment and planning A*, 43(1), 205-223.	7	GIS	Spatial data sources	New Zealand

2.5 Urban design and walking in Asian cities

2.5.1 Urbanisation and motorisation in Asia

Developing countries in Asia have outpaced the rest of the world in both population expansion and growth rate, with the urban population increasing 3.4% per annum, compared to 2.6% in the rest of the developing world (mainly Africa and Latin America), and 1% in developed countries (Asian Development Bank, 2019). By 2050, the urban population in developing Asia is projected to increase by more than 1.1 billion to reach about 3.0 billion with an urbanisation rate of 64%, having half of the world's mega cities (Asian Development Bank, 2019). Parallel to urbanisation, Asia is undergoing rapid motorisation with both the vehicle number and motorisation index estimated to double in the Southeast Asia region, China and India by 2035. Due to rapid motorisation and urbanisation, policies and investments in transportation are predominantly car-oriented (Ieda, 2010). This car-oriented transport planning together with rising income levels, and

growing dissatisfaction with available transport options like cars and motorcycles force people towards the use of personalized, motorized vehicles (Clean Air Asia Center, 2013). Some countries like China and India have opted for rapidly building more roads with China tripling its paved roadway network and India adding one million paved lane kilometres in just one decade (Clean Air Asia Center, 2013) However, this strategy increases travel demand and car use, and thereby, the more need for roads as per theory of induced demand (González & Marrero, 2012). Many Asian cities do not have enough land and financial resources to build more roads and even if they can, the construction of roads would be outpaced by urbanisation and motorisation since infrastructure projects often take a long time to be approved and constructed (Clean Air Asia Center, 2013). If governments in developing countries continue to invest most of the public resources available for transportation in support of the automobile, they will end up with a system built for the small fraction of their people who own cars—15 percent or so in many countries (Brown, 2013).

2.5.2 Walking in Asian Cities

Asian cities are traditionally very walkable and rely on walking for daily travel. Many cities still have relatively low motorisation levels despite the current surge in personal vehicle ownership. Barter (2000) highlighted that walking constituted a significant proportion of overall trips in Asia up to the last decade of the 20th century. Sharing similar results, research by Leather et al (2011a) showed that pedestrian mode share in many Asian cities is great, ranging from 40% in Pondicherry, India to as high as 63% in Chongqing, China. Even in cities with high motorisation rates, Asian cities still have a high walking mode share. In Bangkok, which has one of the highest motorisation rates in Asia with 388 cars and 220 motorcycles per 1,000 people, a significant proportion (40%) of the population relies on walking (Leather et al., 2011a)

Such high levels of walking are due to several reasons. First of all, the high urban density in Asian cities makes them very walkable. Average urban densities range from 10,000 to 20,000 residents per sq. km, which is almost double the rates in Latin America, triple those in Europe, and 10 times those found in US cities (ESCAP, 2010). Moreover, Asian cities have been dense for centuries. Beijing's Hutongs, Hanoi's Old Quarter, Delhi's Katras, and Ahmedabad's Pols today provide examples of how dense these cities already were in medieval times (ESCAP, 2010). Secondly, mixed land use has long existed in Asian cities with most urbanised land being moderately or heavily mixed-use

(Chen, Chiu, & Lin, 2020). For example, the ordinance of Taipei city contains 56 land-use types and 12 land use zones, and each land use zone permits more than 10 types (Cerin, Macfarlane, Ko, & Chan, 2007; Shih, Chang, & Popper, 2018). In Hong Kong, one can easily find 10 restaurants on just a single street block with different options from Chinese, and Southeast Asian cuisines to Western fast food (Zhao, Sun, & Webster, 2020). Thirdly, in many poor countries in countries, walking is the main mode of transport for people often because they cannot afford or do not have access to other transport (Leather et al., 2011a)

While walking mode share is significant, it is declining across Asian cities. Significant drops in walking mode share have been reported across Asia, ranging from 5% in Nanchang (from 2001 to 2005), 16.6 % in Changzhou (from 1986 to 2006), 18% in Delhi (from 2002 to 2008), 25% in Chennai (from 2002 to 2008), 27.6% in Shanghai (from 1986 to 2004) and as much as 35.7% in the Bangalore (from 1969 to 2009) (Leather et al., 2011b). Rapid urban development and prioritization of road networks for motor vehicles over public and active transport networks have led to a poor walking environment with unpleasant, inconvenient, or even dangerous pedestrian routes alongside congested roads (ESCAP, 2015). Cities like Hanoi have a high percentage of short-distance trips, but poor pedestrian infrastructure makes people give up walking in preference to private modes of transport such as motorcycles (Schipper, Leanh, & Orn, 2008). Another important reason for the decline of walking in Asia is the lack of relevant policies, dedicated institutions, political support, investment, and practice that cater to the needs of pedestrians (Leather et al., 2011b). Walking is often neglected in urban transport planning at low administrative division in Asia (Mateo-Babiano & Ieda, 2007). Recent research on city planning policies of 25 cities shows that Bangkok and Hanoi had the largest healthy and sustainable policy gaps with the absence of policies for walking and pedestrian infrastructure (Lowe et al., 2022).

2.5.3 Urban design and walking in Asia Cities

Most studies from North America, Australia, and Europe have demonstrated that areas with higher levels of the three D's (density, design, diversity) also have higher rates of walking (Ewing & Cervero, 2010; Grasser, Van Dyck, Titze, & Stronegger, 2013; Saelens & Handy, 2008; Van Holle et al., 2012). While some studies from South America and Asia report non-significant or even contrary findings in the association between the three D's and walking (Gómez et al., 2010; Su et al., 2014a; Su et al., 2014b; Xu et al.,

2010); suggesting more research should be undertaken to understand better this complex relationships in contexts other than Western ones. This highlights that literature on the relationship between urban design and walking in Asian cities is very limited. The section below summarises some recent efforts in this field of research in Asian countries.

In the context of the cities Bangkok and Jakarta, working with a model of street vendor activities as sidewalk services together with pedestrians' perceptions, Hidayat et al. (2011) found that "Comfort" and "Vendor problems" play a vital role in the level of services for pedestrian. Exploring the impact of the built environment on the duration and frequency of walking in Taipei, Lin and Hsia (2007) reported a negative association between transit accessibility and walking duration and a positive association between neighbourhood environmental quality and walking frequency and duration. The awareness and attitudes of residents of major cities in Japan toward walking have also been explored by Tsukaguchi et al. (2007), which suggests that people consider "walking" as a positive activity and prefer to walk along routes with attractive scenery and surroundings.

There are also efforts to develop a completely new walkability index to suit Asian cities. For example, Wibowo et al. (2015) built a walkability index and found little difference in the overall quality of walking across four types of urban fabrics (education, commercial, city terminals, and worship) in Bandung, Indonesia. However, the detailed index's sub-parameters revealed that walking infrastructure for disability was in worse conditions (Wibowo et al., 2015). Reisi et al. (2019) also developed a walkability index by applying a set of 13 built environment indicators contained within three over-arching categories (safety, quality, attractiveness) and validated the index on Chaharbagh Abbasi Street, one of the main historical, cultural, commercial and entertainment centres in Isfahan City, Iran.

Various researchers have adapted perceived measures tools such as NEWS (Saelens et al., 2003a) to study the relationship between urban design and walking in the Asian context. Appling the NEWS tool to the context of Taiwan, Hsieh & Chuang (2021) reported that residential density, land-use mix diversity, and pedestrian/traffic safety were associated with purposive walking while perceptions of aesthetics and crime safety were associated with discursive walking. Adapting the tool to the Republic of Korea but using the abbreviated version (NEWS-A), Kim et al. (2016) concluded that land use mix-diversity and land use mix-access were positively associated with rates of walking in the city of Seoul.

The framework of urban design qualities developed by Ewing and Handy (2009) has been used in various studies and measured using observational audits. For example, Hasan, Rahman & Siddika (2022) showed that in Bangladesh, walking preferences were associated with factors related to legibility, transparency, and human scale. Using the same framework, a study by Khetrapal & Chadchan (2019) evaluated the urban design qualities of selected streets in Gurgaon (India) and found that streets there have significantly high imageability and complexity quality but show a low sense of enclosure. Integrating the sense of place indicators into Ewing and Handy's urban design qualities framework, a study in Indonesia by Nugroho & Zhang (2022) found that the participants can experience a sense of place – defined as a factor influencing the qualities of people's relationship with a place - through physical and non-physical features at a walking speed because they could observe more details at walking speed.

Some researchers use Walk Score (walkscore.com) - an online walkability index, to measure urban design related to walking in their studies. For example, a study by Koohsari et al. (2018) conducted in Japan found that a higher Walk Score was associated with walking for commuting and walking for errands. In another Japanese study, Koohsari et al. (Koohsari et al., 2021) reported that Walk Score was also positively associated with perceived walkable environment elements. They called for further research is needed to confirm these findings in the ultra-high density context of Asia cities.

2.6 Weather, pollution, and walking

Walking is a physical activity that happens outdoors. Therefore, pedestrians are exposed to weather conditions, air pollution, and noise, where it exists. All of these factors have been linked to negative health outcomes and may influence people's decisions to walk. However, there is little empirical research that has examined the influence of weather conditions, air quality, and noise on decision-making and the prevalence of walking.

2.6.1 Weather and walking

Bad weather (e.g., excess rain, heat, cold, humidity) can act as a barrier to engagement in physical activity. The perception of weather as a barrier to physical activity, as well as a variable shaping an individual's self-efficacy to engage in physical activity, was found to be a significant factor, especially among women (Gallagher et al., 2014). For example, when faced with perceived environmental barriers, including

inclement weather, women were significantly less confident in their ability to walk in their neighbourhood both overall and for increasing durations, as compared to older men (Gallagher et al., 2014). Additionally, within the qualitative literature, insufficient sidewalk and street maintenance related to weather (e.g., lack of snow, ice, or slush removal, pools of rainwater on sidewalks or street corners) was cited as a key barrier to physical activity engagement (Chippendale & Boltz, 2015). A study (Clark et al., 2013) in Canada concerning the weather variables found that average temperature and total precipitation impact walking rates. This study suggested that increasing walking as a mode of transport might be difficult to achieve in climates where there are consistently low temperatures or precipitation and frequent rain (Clark et al., 2013). Campos et al. (2003) showed that lighting, footway width, footway gradient, weather, and proximity to transport facilities or signage were major factors influencing people's decisions to walk. Both studies by Clark et al. and Campos et al. were conducted in countries with cold climates. However, a study in Hong Kong, which has higher temperatures than Canada and the United Kingdom, also found that the participants suggested having a weatherproof environment met their needs as pedestrians and led to an increased likelihood of walking (Hung et al., 2010).

2.6.2 Air pollution and walking

Exhaust fumes or other forms of air pollution may prohibit individuals from walking outdoors. An et al's (2018) systematic review synthesised the peer-reviewed literature on the impacts of air pollution on physical activity or sedentary behaviours for adults. All reviewed studies found air pollution levels to be negatively associated with physical activity, with a meta-analysis of US studies revealing that each one unit ($\mu g/m^3$) increase in ambient PM2.5 concentration was associated with an increase in the odds of physical inactivity by 1.1% among adults (An et al., 2018). Study participants (in particular those with respiratory disease) self-reported a reduction in outdoor activities to mitigate the detrimental impact of air pollution (An et al., 2018). Research on individuals' walking preferences by Bunds et al. (2019) found that air pollution level was the most important attribute, followed by traffic, noise level, and the natural environment. The study by Li and Kamargianni (2017) on seasonality effects of air pollution on mode choice reported that air pollution was negatively correlated with walking in both winter and summer and travellers tended to switch to other motorised transport modes when air pollution levels increased, thereby adding more pollution to already polluted air.

2.6.3 Noise pollution.

Exposure to a high level of noise can lead to negative emotional states including stress, thereby reducing the quality of pedestrians' walking experiences (Ferrer, Ruiz, & Mars, 2015). Seneviratne and Morrall (1985) identified noise as a factor affecting route choice, however their findings also showed that few people considered noise to be the main factor affecting their decision-making. Bunds et al. (2019) also reported that low noise levels increased people's preferences for leisure-time walking however noise was less important than air pollution, traffic, and the perceived quality of the natural environment. They also reported that males put more emphasis on noise level than females in recreational walking decisions. A study by Franěk et al. (2018) indicated that exposure to traffic noise made people increase their walking speed and the absence of noise or the presence of relaxing sounds (e.g., forest birdsong) enhanced their perception of an environment and made them walk slower.

2.7 Limitations identified in the research literature.

Despite a large number of articles related to walking in the scientific literature, this review of the literature points toward several limitations and challenges.

2.7.1 Limited multidisciplinary and multidimensional approaches

Studies on urban walking are varied ranging across fields such as urban design, public health, and transportation. Research in urban design focuses on approaches to making places lively by increasing pedestrian activity. Transportation planners are interested in understanding how people make decisions about walking as a transportation mode to get from one location to another, whilst in public health, the research on walking is considered as a form of physical activity with potential health benefits. Although all perspectives acknowledge the benefits of walking, their approaches, theoretical grounds, and interests in understanding the relationship between the built environment and walking behaviours vary. This leads to inconsistent findings. For example, public health studies often manage to provide evidence for the relationship between walking and the environment where people live. However, more specific knowledge of urban design is needed, relating to the different attributes of the built environment and what attributes influence walking; this is especially the case if the outcome is to establish urban design guidelines and recommendations to promote walking (Choi, 2012). Another example is the lack of cooperation among urban designers and transportation engineers in research on the impacts of urban design factors on walkability at the micro-scale (i.e., street level)

(Park, 2008). Transportation researchers often overlook the micro-scale walking environment, while urban designers have struggled to develop objective methods to measure and assess that street-level environment (Park, 2008), focusing more on subjective assessments of aesthetics. Therefore, a more comprehensive and multidisciplinary approach is recommended to better understand walking behaviour.

2.7.2 The paucity of research focused on micro-scale urban design.

Due to the availability of data sources related to urban form and objectively measured infrastructure, macro-scale walkability studies together with the well-known D variables are dominant in the literature related to urban environments and walking behaviour. Despite their usefulness and popularity, the D variables are argued to be insufficient to wholly represent urban environments that are conducive to physical activity (Sallis et al., 2011). One of the reasons for this is the challenge of operationalizing the D variables. While the measurement of Density and Diversity is often straightforward, quantifying the remaining D variable, Design, is a challenge (Ewing et al., 2015). The gross characteristics of street networks such as intersection density and block size, which are mostly used to calculate the Design variable, may not translate to the experience of people using the street as much as the micro-features of the streets (Ewing et al., 2015). Another reason for the low accuracy of using macro-scale street networks in describing pedestrian movements is that not all the streets are made for pedestrians and there exist various micro-scale elements such as short-cut alleys, footbridges, and underground paths that do not belong to street networks but contribute greatly to people's walking behaviour. For example, a study by Ellis et al.(2016) showed that footpaths predict walkability better than road networks. The macro variables should therefore be supplemented by subtler qualities of the street environment for a better understanding of the impact of urban design on walking.

Furthermore, a micro-scale urban research approach is often preferential over a macro-scale approach in low- and middle-income countries for many reasons. Firstly, geographic data, which is still challenging to access even in high-income countries, are often insufficient, inconsistent, or not available and are costly to collect data in low- and middle-income countries (Koohsari et al., 2021). Secondly, urban form in low and middle-income countries is often already high density with a considerable mix of uses (Chen et al., 2020). Therefore, focusing on analysing micro-scale urban design, instead of studying macro-scale variables such as density and diversity, can better assist our

understanding. More importantly, micro-scale characteristics of the pedestrian environments can be modified at a lower cost and in a shorter time frame than reconfiguring the macroscale designs (Cain et al., 2014), which fits the rapid and fragmented urbanisation and the limited resources of those countries. Given the important role that micro-scale urban design could have in positively affecting walking behaviour and the limited number of studies focusing on this scale, more studies on micro-scale urban design are needed.

2.7.3 Walking is underreported

A major limitation of existing walking literature is the underreporting of the prevalence of walking, itself. The first reason comes with the way researchers define and categorise walking trips. Walking is normally divided into two categories (transport-related walking and recreational walking), and in the majority of studies, only one subtype of walking is being investigated (Höjemo & Fedrizz, 2017; Spinney et al., 2012). For example, studies of leisure-time physical activity overlook walking for transport, while most transportation research neglects walking for recreation. Self-reported physical activity surveys are often able to capture recreational walking but not walking for transport activities (Tudor-Locke et al., 2007). On the other hand, self-reported travel surveys have been usually only used to record transportation walking. Hajna et al. (2015) also stated that while utilitarian walking and recreational walking, separately, have been well studied, there is limited understanding of the association between walkability and total walking.

The second reason for underreporting of walking is the inconsistent definition of walking trips and overlooking walking as a part of another journey in surveys and survey instruments. Walking can be a stand-alone mode of transport or minor activity in other modes, but it is often ignored in travel studies. If the question on a travel survey is: “What is the means of transport you used to travel from A to B?”, the respondent will tend to answer by the main means of transport such as a bus or car but often forget the many minutes of walking from home to the bus stop or the car park. Also, traditional travel diaries have self-report problems of inaccuracy and incompleteness of the data collected. Frequently found problems include errors in the time of the trips reported, omission or addition of trips, and delayed completion of diary compromising recall quality (Zmud, 2006). Researchers have highlighted that accuracy is lost when participants rely on recall to fill out diaries when there is extended time between the activity and reporting the

activity (Shiffman, Stone, & Hufford, 2008). Multi-day diaries over-burden participants in both completing and reviewing on recall interviews, and there is the possibility of no significant differences in travel are found when adding more days to the diaries. Accelerometer and global positioning system (GPS) devices have been used in recent years but these methods still have reliability and data completeness issues (Spinney et al., 2012) as well as ethical concerns. There are also concerns about the ability of GPS and accelerometer to detect and validate multiple walking trips involves in a journey. It is important to design an accurate instrument able to capture all variations of walking - including walking trips made as part of a multi-modal journey.

Underreporting of total walking is also a result of the mismatch between research location and walking data. A review by Brownson et al. (2009) showed that 65% of studies on walking and the urban environment were based on a defined neighbourhood buffer. Examining neighbourhood walking, alone may significantly underestimate the amount of walking, particularly for walking trips associated with active transportation (Millward et al., 2013; Spinney et al., 2012). Several studies measured the neighbourhood-built environment, but the active transport data were calculated by the number of trips that happened both in and outside the neighbourhood (Wang & Wen, 2017). Similarly, Williams et al. (2008) suggested that walking as a dominant form of physical activity can take place both at home, at work or in place of recreation. Research instruments should also be able to filter out trips that occur in or out of defined research boundaries.

2.7.4 Quantity or quality of walking?

The third issue of urban walking literature is the question of quantity or quality. Many studies on urban walking have focused on the amount of walking such as daily walking time, walking frequency, walking distance, or pedometer-based step counts, but seldom focus on features that enhance both the quality *and* quantity of walking. Qualitative factors like a sense of place, liveliness, safety, litter, or aesthetics tend to be missed in quantitative measures (Talen & Koschinsky, 2013). This trend is logical because increasing walking is usually the policy objective to improve health (Adkins, Dill, Luhr, & Neal, 2012). However, to walk more will not be a positive thing if we have to walk in uncomfortable or even hazardous conditions like polluted air or harsh weather. The challenge should be to find urban design factors that affect walking positively (or enhance walking) rather than only cause people to walk more. Success should not merely

be measured by the duration or number of walking trips, but also by the quality of those trips regarding user experience (Adkins et al., 2012). In addition, environmental factors like weather and pollution may influence walking behaviour largely, especially in developing countries where the level of pollution is often higher (WHO, 2021).

2.7.5 Underrepresentation of research in low- and middle--income countries

Last but not least research gap in the walking literature is the underrepresentation of studies in developing countries. The majority of research on urban walking was conducted in the United States, Canada, Australia, and other developed countries. (see Figure 2-4). Despite those efforts in understanding urban transport, studies that focusing on walking in low- and middle-income countries are still scant in the literature. In many developing countries, walking still acts as an important mode of getting around since it is free for low-income residents with limited transport choices (Leather et al., 2011b). However, this sustainable transport mode is threatened by the rapid motorisation and urbanisation process in these countries. The shift of walking research focus to developing countries is important since the urban population in developing countries is set to double by 2050 while remaining stable in developed countries.

It is also necessary to explore how urban form, socio-demographics or culture in these countries influence the relationship between urban design and walking. Studies have shown that urban forms are significantly different between developing and developed countries (Chen et al., 2020; Thompson et al., 2020). For example, urban forms in low and middle-income countries in Asia are often high density with a vibrant mix of uses (Chen et al., 2020), which usually come from historical fluctuations and unregulated development rather than official planning (Storch, Eckert, & Pfaffenbichler, 2008). Findings on urban design from the developing countries suggest that relationships between urban features and physical activity in the developing countries may be complex and may be different from those in high-income developed countries (Gómez et al., 2010; Ho, Stevenson, Thompson, & Nguyen, 2021; Parra et al., 2011).

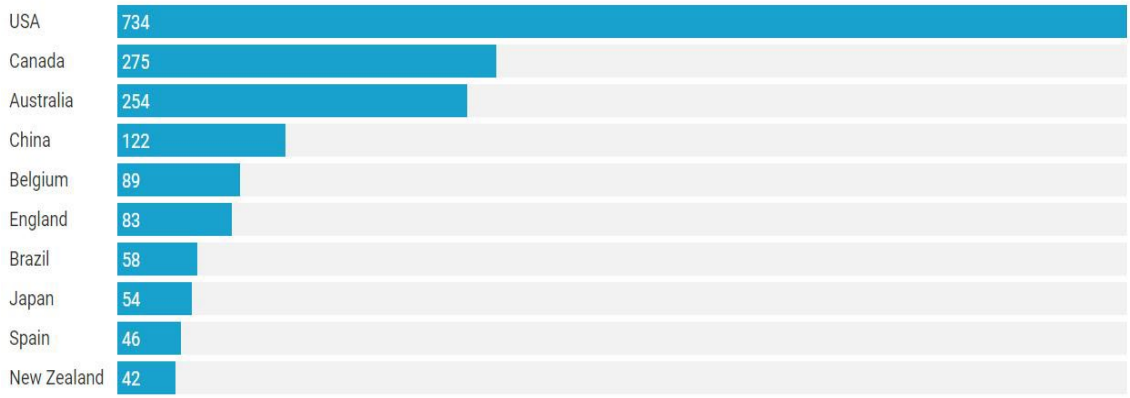

Figure 2-4 Top 10 locations of walkability research.
Source: Search conducted on Web of Sciences database.

2.8 Summary

Evidence from the literature reviewed above confirms that urban design has significant impacts on walking. However, the literature still has several limitations in terms of both research theories, approaches, and methods. As well, the most important gap lies in the fact that research in this field is exceptionally underrepresented - to the point that almost non-existent - in low- and middle--income countries in Asia, particularly in Vietnam. Therefore, a study on walking and urban design in Hanoi - the capital of Vietnam, is essential to fill in this gap in the literature.

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CHAPTER 3 CASE STUDY: HANOI

3.1 Introduction

Vietnam is currently experiencing one of the most rapid urbanisation in the world with a doubled urban population over the last thirty years (UN, 2018). The percentage of the urban population is projected to be 50 % by 2039 and 60% by 2050 (UN, 2018). Being the capital of Vietnam, Hanoi is the oldest, largest, and second-most populous city in Vietnam. It is also the cultural and political centre of the country. Understanding the context of Hanoi is essential to studying its urban design and urban walking. This chapter reviews the current context of the capital city through its general information, history of urban developments, typical urban typologies, urban transport, walking, weather, and level of pollution.

3.2 General information

Hanoi is located within the Red River Delta in the northern region of Vietnam. Most of the city's area lies within the delta which has an average height of 5 to 20 meters above sea level. It is bordered by Thai Nguyen and Vinh Phuc provinces in the north, by Bac Ninh and Hung Yen provinces in the east, by Phu Tho provinces and Hoa Binh in the west, and by Ha Nam provinces in the south.

Hanoi covers a land area of 3,359.8 km^2 and its urban management structure is organized into a set of spatial units. The municipality is divided into Rural districts (*huyen*) and Urban districts (*quan*) (see Figure 3-1). The Urban districts are divided into Wards (*phuong*). The rural districts are divided into communes (*xa*), commune-level towns (*thi xa*) and some towns (*thi tran*). Currently, the city consists of 12 urban districts, one district-levelled town, and 17 rural districts with a total of 175 wards, 21 towns, and 383 communes.

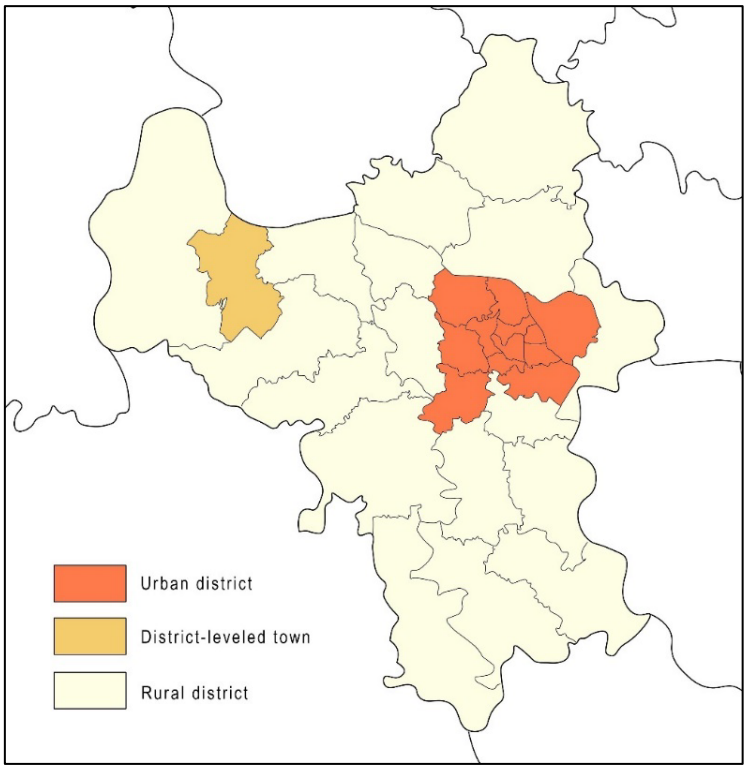

Figure 3-1 Hanoi's urban districts and rural districts.

The administrative boundaries of Hanoi were altered several times throughout the twentieth century. In 2008, the Vietnamese government conducted a large expansion of the administrative limits of Hanoi by merging the entire Hà Tây province, Me Linh district of Vinh Phuc province, four communes (Tien Xuan, Yen Binh, Yen Trung, Dong Xuan) of Hoa Binh province, transforming Ha Dong into an urban district, and downgrading Son Tay to a district-level town (see figure 2). The annexation of these territories tripled the area of Hanoi from 900 km2 to 3,300 km2 and doubled its population from 3 million to 6.4 million. The city has a current population of 8.24 million with an urban population of 3,96 million (Ha Noi Statistics Office, 2021). The average population density is 2.398 persons per 1 sq. km but is unevenly distributed and can reach almost 40,000 persons per sq. km in the city centre (Ha Noi Statistics Office, 2021).

Focusing on urban design and urban walking, this thesis refers to Hanoi as only the urban core area that includes 12 urban districts and excludes all the rural districts and the district-level towns. The details of administrative divisions, area, population, and population density are described in Table 3-1

Table 3-1 Administrative divisions, area, population, and population density of Hanoi's urban districts. Source: Ha Noi Statistics Office (2021)

Urban district	Area (km²)	Population	Population density (people/ km²)	Subdivisions
Ba Dinh district	9.21	226,315	*24,572*	*14 wards*
Bac Tu Liem district	45.35	354,364	*7,813*	*13 wards*
Cau Giay district	12.26	294,235	*23,999*	*8 wards*
Dong Da district	9.95	376,709	*37,860*	*21 wards*
Ha Dong district	49.64	382,637	*7,708*	*17 wards*
Hai Ba Trung district	10.26	304,101	*29,639*	*18 wards*
Hoan Kiem district	5.35	141,687	*26,483*	*18 wards*
Hoang Mai district	40.19	540,732	*13,454*	*14 wards*
Long Bien district	60.09	337,982	*5,624*	*14 wards*
Nam Tu Liem district	32.19	282,444	*8,774*	*10 wards*
Tay Ho district	24.38	167,851	*6,884*	*8 wards*
Thanh Xuan district	9.17	293,292	*31,983*	*11 wards*
Total	308.04	3,702,349	*12,019*	*166 wards*

3.3 History of Hanoi urban development

Being the oldest city in Viet Nam, Hanoi has a remarkable history that can be divided into various periods. Any understanding of Hanoi's built environment requires the exploration of its dynamic evolution across periods marked by diverse external influences (Luan, 1997). In each historic period, the appearance and urban design of the city reflect the prevailing dominant cultural influence (Chinese, French, Soviet, and other Western cultures) and political influences (feudalism, colonialism, communism, and market-oriented communism) (Logan, 2000).

3.3.1 Ancient period

Archaeological evidence of human habitation has been found in the area of present-day Hanoi from 10,000 to 20,000 years ago. Although the region was abandoned from about 10,000 to approximately 4,000 years ago due to the coastal inundation, it has been continuously inhabited for the last 4,000 years (Kim, 2015). In the 3rd century BC, An Duong Vuong – ruler of the kingdom of Au Lac, ordered the construction of a fortified citadel named Co Loa and established the capital in Tay Vu, which is north of present-day Hanoi

3.3.2 Under Chinese rule (1st century BC–10th century AD)

In 179 BC, the Au Lac Kingdom was annexed by Nanyue and the capital was part of colonial China. From the 1st century BC, the Han dynasty conquered Nanyue and occupied Vietnam for almost a thousand years, greatly influencing the Vietnamese culture and structures of government (Taylor, 2013). During this period, uprisings against Chinese rule took place frequently. In 939, after overthrowing the Chinese government in Vietnam and proclaiming himself as the new king, Ngo Quyen transferred the capital to Co Loa citadel (present Hanoi) again and established the Ngo dynasty (Kiernan, 2017).

3.3.3 Vietnamese feudal periods (11th–19th centuries)

Although the capital was set in Hoa Lu in 968 by Dinh Bo Linh, Ly Thai To, the first king of the Ly dynasty, started his reign and moved the capital to Thang Long citadel (formerly name Dai La citadel) which is the site of present-day Hanoi. Thang Long developed on the right bank of the Red River and consisted of the Royal Citadel (*Hoang Thanh*) and the Commoners' City or Imperial City (*Kinh Thanh*). Royal Citadel had four gates: Tuong Phu in the east, Dieu Duc in the north, Quang Phuc in the west, and Dai Hung in the south. Inside the Royal Citadel, there were palaces, houses, and stores to serve the King, the royal families, the members of the royal court, the mandarins, and the aristocracy. The Imperial City was outside Royal Citadel with many streets, guilds, markets, and houses. The most vibrant area was the market town called "Thirty-six guilds" (today known as the Ancient Quarter) located between the citadel and the Red River in the east. Following the Ly dynasty, the Tran dynasty continued to reside in Thang Long and constructed Dai La imperial city. The capital was moved to Vinh Loc (Thanh Hoa province) by Ho Quy Ly in 1397, changing Thang Long into Dong Do. In 1408, the Chinese Ming dynasty invaded Viet Nam, changing Dong Do into Dong Quan. In 1428, Le Loi defeated the Minh and founded the Le dynasty. Thang Long was chosen again to be the capital but changed the name to Dong Kinh (see Figure 3). In 1527, the Mac replaced the Le and returned the old name, Thang Long to the capital. In 1802, Gia Long founded the Nguyen dynasty and resided in Hue. Thang Long was left to be the capital city of the 11 northern provinces. In 1831, Minh Mang King changed Thang Long into Ha Noi, the capital city of Ha Noi Province.

3.3.4 The French Colonial Period (1873 – 1954)

The decision to invade Vietnam was made by Napoleon III in 1857. On 31 August 1858, a French naval vessel attacked Vietnam, starting the colonial conquest. The French

first attempted to seize Hanoi in 1873 (see Figure 4), then returned later in 1882 and successfully occupied the city. In 1883, France's colonization of Vietnam began, and the French Indochina Union was established. Hanoi became the capital of French Indochina between the years 1902 - 1953.

Figure 3-2 Hanoi map in 1873.

Source: National Library of Australia

During this Colonial Period, the French applied both the colonial exploitation programs (called economic exploitation) in parallel with urban construction and planning in Hanoi. The main purpose of the economic exploitation was to exploit the resources of the local region for direct export to France with rice, coal, rare minerals, and later also rubber as the main products (Turley et al., 2021,). This concentration of production

attracted people from rural areas to immigrate to the city to work, leading to significant growth of the city's population from 70,000 in 1918 to 130,000 in 1928 and 300,000 in 1942 (36phophuong.vn, 2011). Among 150,000 Hanoi inhabitants in 1936, there were approximately 5,000 French.

In terms of construction and planning, the French had levelled out the ancient citadel and then constructed important buildings such as military headquarters, Governor-General's palace, ministry buildings, the post office, and the Opera House, together with major infrastructures such as streets, avenues, railways, and Long Bien bridge (Logan, 2000). The French also renovated the Ancient Quarter and surrounding areas, developed the French Quarter in the south area of Hoan Kiem Lake, and expanded the city area in the west direction. The French Quarter was designed and built using the zoning method, which is new to Hanoi. At that time, the traditional urban structure popular in Hanoi and Asia, in general, was the natural mixed-use model without any official design. The urban form of the French Quarter was characterized by the checkerboard-shaped grid, forming neat blocks which had been prepared with technical infrastructure, trees, and street equipment in advance. The area of Hanoi increased substantially from 9.5 square kilometres in 1904 to 130 square kilometres in 1942 (36phophuong.vn, 2011).

Figure 3-3 Hanoi's streets in the French colonial period.

Source: Manhhai CC BY 2.0

Following the start of World War II, the Japanese replaced the French to occupy Hanoi in 1940. Vietnam declared independence on 2 September 1945 and war against French occupation broke out on 23 September 1945 and the French took control of Hanoi in 1946. The French left Hanoi in May 1954 after their defeat at Dien Bien Phu.

3.3.5 Post-French Colonial period (1955 - 1965)

As a result of the 'Geneva Agreements' Vietnam was divided into 2 States, North and South Vietnam. Hanoi became the capital city of North Vietnam - the Socialist Republic of Vietnam with the help and under the influence of countries of the Soviet bloc (USSR, China. etc.). In this period, Hanoi opted for socialism with the USSR as a role model. The city conducted the urban development using the framework called national three/five-year. Hanoi focused on recovery after the war in the first three-year plan (1955-1957) and focused on renovation and development in the second one (1958-1960). The city managed to restore production facilities, and major transport routes, take over and maintain technical and infrastructure facilities from the French, and construct new businesses production of consumer goods and housing facilities. Hanoi's footprint expanded to 586.13km2 (inner city: 37km2, suburban: 549km2) with the population of 913,428 people (inner city: 436,820 people, suburban: 449,608 people) (Ngoc, 2019).

The first five-year plan (1961-1965) focused on building material and technological foundations and industrialization. Several large architectural works such as administrative office buildings, schools, and hospitals were built including the Hanoi University of Science & Technology, Hanoi National University of Education, and Vietnam Cuba Friendship Hospital. The concentration on industrialization was reflected through the construction of many industrial areas namely Thuong Dinh, Vinh Tuy, Thanh Tri, Minh Khai, Chem, Cau Duong, Yen Vien, and Dong Anh. To meet the demand for housing, the Soviet model of collective neighbourhoods was introduced with the five-storied prefabricated residential apartment as the main building type. Kim Lien and Nguyen Cong Tru were the two first neighbourhoods that followed this collective housing model. In addition, Hanoi also renovated public parks such as Thong Nhat Park.

3.3.6 Vietnam-American War (1965-1975)

In attempts to prevent Hanoi from stimulating economic development, the USA expanded the war in the South to the North, which involved the bombing of North Vietnam with a focus on Hanoi. Many waves of the bombing were dropped on Hanoi from 1966 to 1972, destroying major parts of the city and killing large numbers of people. Several important buildings and infrastructure such as hospitals, railway stations, bridges, and thousands of houses were destroyed. Hanoi had to decentralize its economy and evacuate large numbers of people to minimize the impact of the bombing. In 1972, the Americans announced the cessation of bombing after a heavy defeat called “Operation Dien Bien Phu in the air". Among many options for re-developing the capital, a planning project to enlarge the capital to Vinh Yen and connect Hanoi with the surrounding townships such as Xuan Mai and Son Tay (Ngoc, 2019) was selected. However, this project was not implemented. In 1975, North Vietnam attacked Saigon and manage to defeat South Vietnam’s government backed by the USA, bringing three decades of war to an end (Logan, 2000).

3.3.7 Post-independence period (1975-1985)

The reunification of the country in 1975 opened a new stage of development for the whole country and the capital Hanoi. New requirements required adjustments to the master plans created in 1961. In 1981, with the help of Soviet experts and foreign experts, the government approved the Master plan of the Hanoi capital toward 2000 with an estimated population size of 1.5 million people. The boundary of Hanoi was expanded by merging with Ba Vi, Phu Tho, Thach That, Dan Phuong, Hoai Duc, Son Tay, Ha Dong,

Ha Dong, and some communes of Ha Son Binh province. After this expansion, Hanoi progressed from 4 urban districts and 4 rural districts, including 78 sub-zones, 104 communes, and 9 towns with a total natural area of 586.1 km2, has increased to 4 urban districts, 11 rural districts, and 1 town, including 78 sub-zones, 266 communes and 12 towns with a total natural area of 2131 km2 and a population of 3.5 million people. In 1979, the northern border war with China broke out, making the master plan of urban development to be adjusted again in 1982. Although there were difficulties, this was also the period that has the highest speed of urban construction, especially in housing. From only 50000m2 of housing in 1980, 450000m2 of houses were built together with necessary social infrastructures such as kindergartens, schools, and public works in the period of 1981-1985.

3.3.8 The post-Doi Moi period (1986-present)

In 1986, Vietnam took a major economic reform called “Doi Moi” (renovation), which completely changed the economic system from a centralized socialist economy into a market-oriented socialist economy (Beresford, 2008). While maintaining a communist political structure of government, Vietnam conducted a major switch of economic reform including decollectivizing agriculture, ending state subsidies, reducing the number of state-owned enterprises, and encouraging the private sector in what was officially referred to as the 'multi-sectoral' economy (Fforde, 1997; Logan, 2000). The economy was also more open to international sources by encouraging foreign investment and international trade.

This shift in the economic structure had a strong impact on Hanoi's urban development. The first impact was reflected by a sharp increase in unregulated and illegal building activity (Smith & Scarpaci, 2000). The growth in the industrial and service sectors created more job opportunities and better social services, luring more people to the capital city (Nguyen, 2016), thereby, increasing the demand for housing. The inner city was densified extensively, and suburban villages were urbanized rapidly to cope with that unprecedented demand (see Figure 3-4). However, most of those works are self-organized and unplanned developments instead of official macro planning. Ignoring all the construction regulations, people divided their land plots into smaller plots for selling and redeveloped their houses as big and high as possible (Ngo & Gao, 2018) to maximize built-up areas and living spaces, resulting in very high building density. In the late 90s, over 70 per cent of the residential housing in Hanoi was invested by private households

and built by private small builders, generally without construction permits (Koh, 2006). This self-help and informal housing production process created numerous issues such as a lack of urban services and infrastructure to service residents. Local planners therefore considered it a suboptimal solution to the city housing shortage (Labbé, 2021).

Since 2000, Hanoi witnessed another trend in urban development when the state sector regained its leading role in urban building activities through institutional restructuring measures (Waibel, 2004). State enterprises like the Housing and Urban Development Corporation (HUD) or Vietnam Construction and Import-Export Joint Stock (Vinaconex) designed and developed many new urban areas across the city. These new urban areas, which were often planned carefully and come with adequate infrastructure, attracted the emerging middle class of the city (Waibel, 2004). There were about 240 new urban areas approved from 1996 to 2015 with the size ranging from a few hectares to hundred hectares (Labbé, 2021). In recent years, these projects were mainly developed by domestic large enterprises, however, foreign investors and developers, especially those from Korea, have also entered the market.

Figure 3-4 Density of informal development in Hoang Van Thu ward.
Source: Google Maps (2022)

This policy change is also reflected in urban planning and urban management which has shifted from rigid, top-down Soviet-style Master Planning which comprised five stages, to a more flexible, strategic Planning and urban management approach that is

currently being implemented in Hanoi. The new planning approach only includes only two stages: (i) Master Plans for a period of fifteen to twenty years which were updated every five years (ii) Detailed Plans that were constructed in fulfilment of the Master Plans (Van Horen, 2005). In 2008, to create development potential, Hanoi was expanded to become the largest city in Vietnam by merging Ha Tay, 4 communes of Hoa Binh province, and the Me Linh district of Vinh Phuc province. The Master Plan of Hanoi to 2030 (see figure 10) with a vision to 2050 was approved in 2011 with the goal of building a "Green - Civilized - Modern" city with an urban cluster model consisting of a central urban area and 5 satellite cities. Up to now, the planning system has covered the whole area with zoning plans, master plans, and sectoral plans along with more than 70 detailed plans (Ngoc, 2019).

3.4 The five urban design typologies

As highlighted in the above section, Hanoi has experienced many changes to its urban development over more than 2000 years. Those various changes have resulted in a multi-layered urban structure with five different urban typologies, namely the *Ancient Quarter*, the *French Quarter*, the *Collective Housing Quarter*, the *New Urban Area*, and the *Urbanized Village Area.* This section will describe in detail these five urban typologies.

3.4.1 The Ancient Quarter

The *Ancient Quarter*, initially comprising 36 commercial guild streets, was established in the 11th century during the feudal periods and since then it has become the centre of Hanoi (See Figure 3-5). Guilds were originally organized and built fully enclosed and were the living places and workshops for skilled craftsmen originating from various villages in the northern delta (JICA, 2007). When the streets were formed, they traded at the storefront, and moved the storage and living space to the rear of the buildings, creating the shop-house typology known as “tube house”. Being taxed according to the width of the storefront, traditional tube houses were long and narrow (2–4 meters wide but 20- 60 meters long). Although most of these shophouses have been renovated and street functions have changed through the times, streets still have the names of the original guilds such as Hang Bac (Silver Street) or Hang Bong (Cotton Street) (Van Horen, 2005)

Figure 3-5 Ancient Quarter in 1902-1925.
Source: Manhhai CC BY 2.0

Besides the ancient shophouses, the urban design of the Ancient Quarter is also characterized by ancient architectural religious heritage including communal houses, temples, and pagodas since craftsmen brought with them their religious practices when moved from the villages to the capital. The ancient shophouses and religious buildings are important heritage assets of Hanoi and are recognized by the authorities reflecting through various management and conservation policies. However, they are deteriorating over time or illegally interfered with due to the people's living needs, which requires the cooperation of both authorities and residents in conserving, maintaining, or repairing. In terms of the street network, The Ancient Quarter features a dense street network with a high intersection density, and the road area ratio can approach 23.5% (Kato & Nguyen, 2010). Streets and sidewalks in the Ancient Quarter are narrow and often occupied as places of business or parking, however, they are very vibrant and lively, accommodating many residents and tourists.

3.4.2 French Quarter

The acceleration of western foreign influences started with the French colonization (1873-1954), resulting in the establishment of the *French Quarter* (Geertman, 2007). After about 80 years of construction (1875-1945), the urban design of the French Quarter has left beautiful imprints on the capital city with rich and diverse architectural and

planning styles, expressed through various buildings, mansions, villas, street networks, and landscape spaces like parks and lakes.

In terms of architecture, the French applied various styles in Hanoi including Pre-Colonial Style, Neoclassical style, French Local Architectural Style, Indochinese style, and Art Deco (Tran, 2012). The Pre-Colonial Style was used in the construction of barracks for the French army in 1886 and some construction works on the east side of Hoan Kiem Lake in the early period. Neoclassical style was expressed through government buildings including the Governor-General's Palace (now the Presidential Palace), the Reunification Palace (now the Government Guest House), and the Court (now the headquarters of the People's Supreme Court). Neoclassical style is also applied in the design of large economic and cultural works such as the Post Office, Hang Co railway station, Metropole hotel, and Opera House. The local French style influenced the construction of many villas for the French and schools in this period such as Phan Dinh Phung School, Tran Phu School, and Chu Van An School. Art Deco style flourished in the French Quarter in the years 1920-1930 and was especially evident in large commercial buildings such as the headquarters of the Bank of Indochina (now the headquarters of the State Bank), the IDEO printing house (now the French Cultural Centre), the headquarters of the Chamber of Commerce and Agriculture (now the International Post Office) and lots of villas for both French and Vietnamese. The largest representatives of the Indochinese style are the main building of Indochina University, the Louis Finot Museum (now the History Museum), the Indochina Department of Finance (now the Headquarters of the Ministry of Foreign Affairs), and the Cua Bac Church. The French studied carefully details of Vietnamese local culture, architecture, and lifestyle to adjust to the European styles that they brought in. The French architecture style in Hanoi has been tropicalized to suit the local context such as the use of basements, thick walls, and a roof with a large space to increase insulation and heat resistance. The elements such as wooden consoles, Asian roof corners and tops, and decorated details inspired by oriental artworks on the walls, doors, and balcony railings, give a clear impression of an architectural form that combines East-West cultural quintessence (Tran, 2012).

In terms of the street network and urban structure, the French Quarter in Hanoi is characterized by a grid of lines with two main axes East-West and North-South (Vuong, 2019). East-West is the main axis consists of several large boulevards with wide pavements, and many trees, featuring many important buildings which served as urban landmarks including the Hanoi Opera House and Hang Co Station. Streets in the North-

South axis are smaller but play a vital role in connecting urban blocks and important public spaces such as Hoan Kiem Lake or Thuyen Quang Lake. This street network not only creates square blocks but also creates many distinctive shaped spaces often used as flower gardens which is a familiar feature in French urban design (see figure 14).

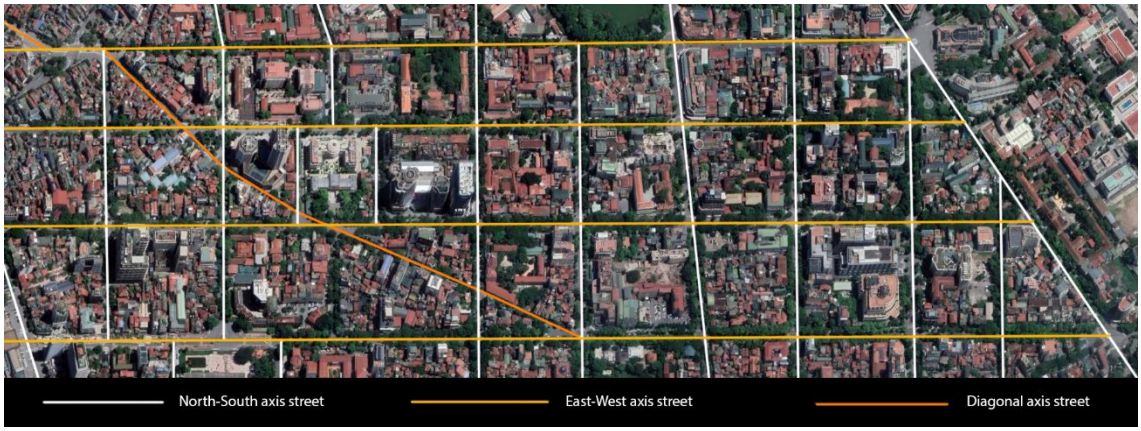

Figure 3-6 Urban form and street network in French Quarter.

Nowadays, the French Quarter is a valuable heritage of Hanoi but is facing similar problems as the Ancient Quarter. Many buildings, mansions, and villas are being seriously degraded and deformed for several reasons: (i) the impact of time and climatic factors, (ii) the uncontrolled urbanisation process causes many heritage buildings to be demolished and replaced by high-rise buildings, (iii) illegal renovation and expansion to meet new demand due to the increasing population and density (iv) the absence of heritage conservation plan and policies (Tran, 2012; Vuong, 2019). The French Quarter needs to be researched, evaluated, and categorized carefully to develop regulations and policies on management and conservation and by plans to implement and monitor conservation works (Tran, 2012).

3.4.3 Collective Housing Quarters

After independence from French colonization in 1957, Vietnam followed socialism taking the design from the Soviets as a model (Geertman, 2007). From the 1960s, models of Soviet-style collective neighbourhoods were constructed across Hanoi. These neighbourhoods, often called Collective Housing Quarter or "KTT" in Vietnamese, were designed to accommodate 7,000 to 12,000 inhabitants and formulated by typical four to five-storied residential apartment buildings as the core structure and public facilities such as parks, community courtyards, schools, kindergartens, and markets.

KTTs have completed the task of filling the demand for housing in the historical period of Hanoi, and at the same time, made an important contribution to the urban design

of the capital city in that period. Some construction design criteria of KTTs still meet the modern criteria of ecological housing construction and sustainable development (Nguyen, 2011). For example, the distance between buildings was guaranteed to be at least 1.5 to 2 times the height. The main direction of the buildings was arranged to adapt to climate conditions with the main wind direction of Southeast and South. Only 15% of buildings were allowed to be arranged in other directions depending on the spatial organization requirements of the areas such as buildings at centre locations or intersection corners. The internal traffic network was designed to be very spacious and conveniently connected to the city's general traffic network (Dang, 2009).

After many years of being put into use, KTTs began to show their own problems. One major problem is that they were originally designed for nuclear families, rather than extended families which are more common in Hanoi, leading to a severe lack of living space within units (Van Horen, 2005). Some KTTs such as Bach Khoa have a household of up to 8 people / 24 m2 (one apartment) or Thanh Cong has a household of 10 people/28 m2 (one apartment) (Dang, 2009). Nguyen Cong Tru is a typical KTT during the subsidy period, originally built to meet the housing needs of about 4,000 people, however, it has become a chaotic "living and business" area with a population of about 9,300 people (Dang, 2009). The second problem is that most KTTs have significantly deteriorated, creating serious maintenance problems and therefore no longer meet contemporary standards of living conditions. These problems led to significant changes of KTTs. Most changes are the result of informal additions or renovation of interior living spaces (Dinh, 2019). The additions are often in form of an extension of an upper dwelling unit or an extension of the ground floor for shop use (Narumi, Bui, & Oka, 2005). Interior renovation often involves activities such as dividing spaces and adding or removing walls, doors, and windows. Both these expansions or interior renovation activities are often illegal and dangerous due to interference with the structure of the building without any formal architectural or engineering designs. For example, to extend or create rooms or spaces that go outside of the apartment’s façade, people often use the cantilever technique and veranda technique using steel or concrete columns and beams that are implanted into the existing structure of the building, then building walls with light materials or iron frames (see Figure 3-7). This type of extension is called “Chuong Cop” or “Chuong Chim” which means “Tiger cage” or “Bird Cage” in Vietnamese. The second most common change was the illegal encroachment on public spaces for personal use. Family-owned shops were added to most units on the ground floors and illegally occupied the

public spaces in front for doing business including motorcycle parking services, coffee, and restaurants. In some extreme cases, houses are illegally built at the banks of ponds in the neighbourhoods (Narumi et al., 2005).

Figure 3-7 Informal modifications and community courtyard in KTT Nghia Tan

In terms of planning, the internal transport system in the KTTs has been overloaded and the original planning function has been changed. Previously, according to the general plan, KTTs were usually located on the periphery of the city, where there is a large area of vacant land and moderate traffic density. Today, due to the rapid urbanisation of the city, the location of these KTTs has become the centre of expansion planning. The internal traffic route of the KTTs has become the general traffic route (even the main traffic route) of the new urban transport system. This situation causes the traffic density on the above roads to increase rapidly to the point of being overloaded and changes the function of the rows of houses on this road from housing to housing combined with business.

Although changes in the KTT are often illegal and problematic, from another perspective, they demonstrate the adaptation process of Soviet architecture and urban design models to the local traditional lifestyles, which has also happened in other parts of Hanoi such as the French Quarter and Ancient Quarter (Dinh, 2019). So, while illegal, these additions provide more residential space as well as provide informal commercial spaces for traditional family-based shops, coffees, restaurants, and workshops, which are vital to the social, cultural, and economic life of individual households as well as neighbourhoods nearby.

3.4.4 Urbanized Village Area

Although the process of transforming villages, especially those near the city centre, into urban settlements has been happening for many decades, the most rapid urbanisation in Hanoi only happened when economic reform (Doi Moi) was initiated in Vietnam in 1986. Without planning and infrastructure development, many villages have been urbanized rapidly to meet the demand for housing during the period of economic growth, creating an urban typology that is referred to as the Urbanized Village Area.

The political-economic reform enacted since Doi Moi has led to significant changes in the population of Hanoi. Rapid economic development has created more jobs, and other social opportunities, attracting people to migrate to Hanoi. Most migrants who came to Hanoi decided to live in urban villages due to reduced living costs (Ngo & Gao, 2018). To take advantage of that increasing housing demand and prices, villagers have renovated their old houses and divided their plots of land in order to resell them or rent them out to newcomers (Bousquet, 2015). Some villagers grouped together their plots of land to sell to property developers at better prices (Cerise, Fanchette, Labbé, Boudreau, & Kiên, 2016). Another reason that led to the urbanisation of urban villages is the transformation of farmlands in surrounding areas. A large number of new urban areas and industrial or commercial centres have been constructed on agricultural land that previously belonged to villages (Ta & Phan, 2021). Although most of the villagers received compensation for the lost farmland, they can no longer farm for a living, and therefore have to find alternative income (Nguyen, Duan, & Liu, 2018). Beside renting accommodation, villagers used their lands and house to start family-based businesses, setting up workshops, warehouses, shops, or small cafés and restaurants. These home-based businesses often offer low prices, targeting low-income groups such as immigrants and students who are renting in the villages.

These spontaneous processes have transformed both structure, land use, and appearance of the villages. The influx of immigrants has almost doubled the population of many villages, making providing accommodation one of the main occupations of the native villagers (Cerise et al., 2016). Most buildings were renovated or rebuilt illegally to maximize built-up area and living spaces, which densified greatly the villages (Ngo & Gao, 2018). The encroachment over ponds and the elimination of gardens also limited the open spaces inside the villages, leaving only religious spaces like Dinh (communal temples) or Chua (pagodas). The use of new materials such as concrete instead of traditional ones along with the spontaneity of housing design also changed the appearance

of villages significantly. In terms of land use, villages have been changed from agricultural/residential communities into high mixed-use urban neighbourhoods. These areas often have an organic road network consisting of many narrow, long, and winding streets that were informally set up based on the former village streets (see Figure 3-8). Secondary to the street network is the alley system which is often narrow, dark, and too small for cars or public transport (Ngo & Gao, 2018).

Figure 3-8 Organic network of streets and alleys of the Urbanised Village Area.

3.4.5 New Urban Areas

Since the 1990s, new residential projects called New Urban Areas, which differ widely from their KTT predecessors, have been planned and implemented across Hanoi. The government defined New Urban Areas as "an urban area that is invested to construct newly and synchronously in terms of technical infrastructure, social infrastructure and housing" (Government of Vietnam, 2009). The goals of the New Urban Area were to accommodate a rapidly growing urban population and to increase government control over urban developments that were 'disordered', 'patchy', and 'uncontrolled' in the past years (Tran, 2015). To achieve these goals, the development of the New Urban Area focused on several aspects including integration, synchronization, modernity, and orderliness, instead of building a collective lifestyle like in the KTT era (Labbé & Boudreau, 2011; Tran, 2015)

New Urban Areas are planned to contain high-rise apartments (60 per cent), landed houses (40 per cent) as well as public facilities such as schools, hospitals, markets, sports

grounds and playgrounds (Hanoi People's Committee, 2001). Each New Urban Area is designed to cover an area of at least 50 ha or more and the targeted population should be from 5000 people or upwards of 1000 households. The subdivision of land plots for the construction of attached houses, the main phenomenon of housing development in past years, is no longer allowed in New Urban Areas. The high-rise towers are placed at the front, near the main streets with the ground floor of buildings reserved for public facilities like offices or commercial premises (Hanoi People's Committee, 2001). However, those offices, banks, supermarkets, and restaurants on the ground floor often have closed façades with only one entrance raised from the sidewalk (Tran, 2015), which opposes the lively, friendly facades proposed by Gehl (2013). The floor plans of those towers are designed not to rationalize space (like in KTTs) but to maximise profit by minimising circulation corridors to save spaces for apartments placed around a very compact core at the centre (Labbé & Boudreau, 2011). Behind the high-rise buildings is a layout of secondary roads that form blocks for two popular housing typologies: the villa and the row house (Labbé & Boudreau, 2011). In most New Urban Areas, the high-rise apartment buildings, as well as the villas and row houses, are designed with limited types to maintain the objectives of 'synchronisation' and 'uniform', making them look identical (Tran & Schlyter, 2010). The landscape features like parks and greenspaces are also designed with the focus on 'orderliness' and 'tidiness' therefore they only serve as pretty green spaces to look at but not to step in, sit on and enjoy (Tran & Schlyter, 2010) Streets are often wide, from 15 to 35 metres, originally designed for car and motorcycle use with a little attention to the needs of pedestrians (Tran, 2015).

Although planning regulations require New Urban Areas to have public facilities such as parks, playgrounds, or sports grounds, many New Urban Areas neglect those public services. Tran (2015) reported the problems of lacking playgrounds, sports grounds, insufficient benches and tables in public spaces, planned public schools being sold to private companies, or planned parks turned into car parks in some New Urban Areas. As a result, residents had to self-organise those services by playing sports on the courtyards or public grounds, collecting money to buy benches, and opening street markets and food stalls (Tran, 2015). In some other cases, social equipment and housing-related services are built after residential buildings and sometimes even after residents have moved in. (Cerise & Maximy, 2010). Investors often require a financial contribution from the resident to accelerate construction, which usually results in long delays. Some

of the buildings in the earliest such projects also suffered extensive defects and deterioration (Cerise & Maximy, 2010)

3.5 Hanoi's urban transport and walking

3.5.1 Hanoi's urban transport

In the feudal period, Hanoi (which was named Thang Long at the time) was totally a non-motorised traffic city. People usually walked or used boats and horse wagons to move around the city. Under French Colonial rule, Hanoi experienced major changes in the city structure with the new networks of French-style wide and well-organized streets. The most important event of this period was the appearance of trams – the very first public transport in Hanoi. After regaining independence, the city kept this very sustainable urban transport system operated by tram, bicycles, and walking. However, after 1990, motorcycles appeared and soon became a part of Hanoi citizens' lives, extensively changing the urban transport of the city

Today, the urban transportation system of Hanoi is primarily composed of both urban and inter-city roads. In 2019, the city has a transport network of 1,147 roads of 2,052 km in total length. However, transportation land use only accounts for 9,38% total area (Pham, 2019). The road network is still inadequate in terms of density, connectivity, and technical standards, except for those in the urban core (JICA, 2007). Urban traffic in Hanoi is mainly carried out by private vehicles made up primarily of motorcycles, a rapidly increasing number of cars, and a decreasing number of bicycles (JICA, 2007). In 2017, there were more than 5 million motorcycles and almost 500,000automobiles in Hanoi, which translates to a total of 2,561 motorcycles and 160 cars on every 1km of road (Pham, 2017). Public transportation services are provided by a bus network of 123 routes, 1 Bus Rapid Transit (BRT) route, and 1 Metro route with another one will be operated soon (Pham, 2019). In addition, there are supplementary public transportation services such as taxis, motorcycle taxis, phasing out bicycle rickshaws (cyclos), and rapid developing ridesharing services. The modal share of active and public transport is only about 10 per cent of total trips (Pham, 2017).

The urban transportation situation in Hanoi has few comparisons with other cities in the world (JICA, 2007). In most major cities in developing countries, private vehicle ownership is low and public transport plays an important role. By contrast, Hanoi has a high rate of private vehicle ownership and a very low mode share of public transport, which is similar to most developed car-dominated cities, albeit motorcycles rather than

cars (Bray & Holyoak, 2015). However, if we compare Hanoi to car-dominated cities, Hanoi has a much higher population density, and the city is also much more compact. The high density, compactness of urban form, and inadequate road infrastructure with a network of many small and narrow streets have facilitated small vehicles such as motorcycles. Such unique arrangements, allow the city to cope with the transportation demands (JICA, 2007), and also provide a high level of mobility at a moderate cost (Bray & Holyoak, 2015). Accessibility is also very high and door-to-door movements are made possible in a short travel time (JICA, 2007).

The urban transport of Hanoi is now facing many challenges. According to Hanoi Transport Department, the growth rate of cars is 10.2% per year and the growth rate of motorbikes is 6.7% per year, while the increase in the urban road length and the land area for transport are only 0.38% per year and 0.25% per year respectively (Hanoi Portal, 2017). With the existing number of vehicles, the calculated vehicle-occupied area is 1.34 times higher than the capacity of the road system (in the central area is 3.72 times) (Hanoi Portal, 2017). This rapid growth in the number of private vehicles together with the limited road capacity and slow infrastructure provision has led to heavy traffic congestion across Hanoi (see Figure 3-9). There are reportedly 27 spots of severe congestion and the economic loss caused by congestion is estimated to be USD 1 billion per year (Pham, 2019).

Figure 3-9 Traffic congestion in Hanoi

The second challenge is the high rate of injurious vehicle crashes, again, partly due to the dominance of private vehicles especially motorcycles which are often more vulnerable than cars due to their exposed design and single-track architecture. Although motorcycle helmets are mandatory, the quality of helmets is often poor, just enough to bypass law enforcement officers and compliance rates are not always high. Another reason for the high rate of traffic crashes is the lack of discipline or disregard for traffic rules by road users and the ineffective traffic management in Hanoi (JICA, 2007). It is common to see motorcycle riders on the sidewalk when there is congestion.

The rapid growth in vehicles also led to a substantial increase in air pollution and noise pollution, resulting in many motorcyclists and pedestrians wearing masks to reduce inhalation of pollution and dust.

3.5.2 Walking in Hanoi.

Hanoi has been a walkable city for most of its 1000-year history. Until recent decades, Hanoi was still dominated by non-motorized transport modes which made it one of the cities with the most sustainable urban transport at that time (Hansen & Andenes, 2016). However, the capital city has turned into the land of motorized transport, especially motorcycles, and become more and more unwalkable.

The foremost reason for the decline of walking in Hanoi is the rapid growth in the number of private motorized vehicles. Research by Tran et al. (2015) showed that most people in Hanoi only walk when trips are under 500m in length. When the distance

increases to 1km – 5km, motorcycles comprise nearby 90% of mode share. Affordability, speed, and ability to carry goods are factors making motorcycles more suitable than walking for the informal economy which is extremely dynamic in Hanoi (Leducq & Scarwell, 2018). Citizens also prefer motorcycles to walking because it's considered more convenient for the hot and humid weather conditions of Hanoi (Bakker, 2018).

Although, most of the arterial roads in Hanoi have roadside facilities such as sidewalks, street plantings, and street lighting, the condition of walking infrastructure is generally poor. The majority of pedestrians interviewed in the research by Leather et al. (2011) considered the pedestrian facilities poor and would like to have improvements in their pedestrian environment or they would switch to other modes of transport. In the central business districts (Ba Dinh, Hoan Kiem, Hai Ba Trung, and Dong Da), sidewalk coverage may reach the level of 80% or more, however, sidewalk coverage is much less in the urban fringes district, except for New Urban Areas (JICA, 2007). The quality of sidewalks is generally not satisfactory with uneven surfaces and many cracks and gaps. The specifications and standards of the sidewalk are inconsistent in width, materials, and construction methods. Some are quite wide, but some are extremely narrow, some have curbs and others have none, some are made of concrete, and some are made of brick or stones. The most problematic issue is the encroachment of the sidewalk for parking, personal businesses, or other unauthorized activities such as dumping garbage or building materials (see Figure 3-10). There are also some other obstructions on the sidewalk like electric posts, cables, and electrical cabinets. All these blockages obstruct pedestrians, forcing them to walk strugglingly in a zigzag path or to walk on the street – which is hazardous and affects the flow of traffic.

Figure 3-10 Pedestrians have to walk on the street due to the obstructions on the sidewalk.

It's also difficult to cross the streets in Hanoi due to the heavy traffic on most streets and the lack of crossing facilities. Apart from the CBD area, it is very rare to see pedestrian crossing lights or pedestrian priority signs in the middle of the street. Car drivers and motorcycle riders often ignore the crossing stripes and don't stop to give way to crossing pedestrians even at some intersections with traffic lights. In most cases, pedestrians have to wriggle through the flow of traffic to cross the street. Research by Leather et al. (2011) showed that 52% of participants in Hanoi would like to have more skywalks due to the high number of traffic accidents and the lack of facilities that provide safe crossings.

Problems also lie in the management, design, and construction of walking facilities. To manage the parking of motorcycles on the sidewalk, white painted lines are drawn on the sidewalk to mark the boundary between the pedestrian area and the parking space. However, the paintwork also creates many problematic situations, as the zigzag line makes both walking and parking more difficult. On many street sections, the sidewalk for walking outside the line is too small, in some places only more than about 30 cm, or entangled in trees and electricity poles, forcing pedestrians to walk on the road. In some parts of Hanoi, sidewalks are fenced off by authorities to prevent motorcycles from riding on the sidewalk, but pedestrians crossing the street are forced to climb the fence to reach

the sidewalk. It is also quite common when the crosswalk is blocked at one end or leads to an impassable area (see figure 3-11).

Figure 3-11 Sidewalk guarded fence, electric cabinet and traffic light block the crosswalk

In terms of policies, recent research on city planning policies of 25 cities showed that Hanoi is one of the countries which had the largest healthy and sustainable policy gaps with the absence of specific policies for walking and pedestrian infrastructure (Lowe et al., 2022). The Hanoi government has also made some efforts to regain pedestrian space, such as issuing bans on parking on sidewalks in some streets, banning and penalizing activities that encroach on sidewalks for business activities, and destroying constructions encroaching on sidewalks. Such measures are sometimes problematic in terms of organization and implementation. Those measures also face resistance from the residents or only have a temporary effect.

Until now, Hanoi's most successful effort in promoting walking is the establishment of pedestrian streets. In 2004, the city opened the first pedestrian street through Hang Dao - Hang Ngang - Hang Duong - Dong Xuan - Hang Giay. In addition to shops on both sides of the road, there mobile stalls were installed in the middle of the road selling mainly handicrafts, high-quality Vietnamese goods, and goods for tourists, with 3-3.5 m wide on

both sides as walkways. Since then, Hanoi has added pedestrian streets three times. In 2014, the walking space was expanded to 6 more streets in the first-class conservation area - Hanoi Ancient Quarter. By 2016, the pedestrian street area continued to be expanded with the pedestrian space in Hoan Kiem Lake and its vicinity including 16 streets. In 2020, 8 more streets were added, raising the total number of pedestrian streets to 32. Among them, the walking space of Hoan Kiem Lake and its vicinity has been the most successful walking area, becoming a tourism brand and famous destination for locals as well as domestic and foreign. This walking area is always full of activities and services, attracting about 20,000 visitors per day (see Figure 3-12). It has also held hundreds of multiscale international and local events. However, most of these pedestrian streets only open during the weekend (from 19.00 on Friday to 24.00 Sunday). Also, there are some pedestrian streets that are not very successful, for example, the pedestrian space in Trinh Cong Son Street, Tay Ho District opened in 2018. Activities on Trinh Cong Son Street are not well supported, with few restaurants, bars, and individual artistic activities. During the day, very few people come because of the hot sun due to the lack of shade (Vo & Pham, 2022). Hanoi is planning to open more walking spaces in other districts rather than just the central district – Hoan Kiem.

Figure 3-12 Trang Tien, a pedestrian street.

3.6 Hanoi weather, air and noise pollution.

3.6.1 Weather

Hanoi is located in a tropical climatic zone with full four seasons: Spring, Summer, Autumn and Winter. Spring begins in February (January according to Lunar Calendar) and is characterized by drizzle and monsoon rains. Summer, from May until August, is characterized by hot weather and high rainfall, often resulting in frequent flooding. September to October is autumn, characterized by a decrease in temperature. Winter, from November to January, is dry and cold. The annual average rainfall in Hanoi is 1678 mm. Temperatures range from lows of 6°C in winter, to 45°C in summer. In Hanoi, a person can feel hotter in summer and colder in winter that the dry-bulb temperature may indicate due to the high humidity and the winter monsoon (the northeast monsoon). Under such weather conditions, walking becomes quite difficult, especially during summer and winter. In the summer, people usually don't walk outdoors around noon. Pedestrians often wear sun protection clothing, hats, or umbrellas (see figure 33). Due to the high humidity, pedestrians also often experience heavy sweating which leads to dehydration and body odour. This discourages many from choosing to walk to work. In the evening, it often rains heavily, leading to flooding on many streets, making walking even more difficult (see figure 3-13)

Figure 3-13 The street is flooded after the rain, making it difficult to walk

3.6.2 Air pollution

In Hanoi, pedestrians are also exposed to very high levels of air pollution as they often walk along these busy roads. In a study by Saksena et al. (2008) in Ha Noi, pedestrians were found to be exposed to 495 µg/m3 of particulate matter (PM_{10}), and 8.5 ppm of carbon monoxide (CO). This level of air pollution exposure is problematic because the guideline of the World Health Organization for PM_{10} is only 50 µg/m3 for 24-h means. Motorised road transport activities are determined to account for 70% of the sources of air pollution (Hanoi Portal, 2017). In particular, the motorcycle fleet, the dominant mode of transport in Hanoi, was the main contributor to the traffic pollution, varying from 35-47% for CO2, SOx, and NOx, 70% for CO and PM, to 80% for air toxics and 88% for VOCs (Trang, Van, & Oanh, 2015). Air pollution is also found to be higher in rush hours in comparison to non-rush hours (Tang, Oanh, Rene, & Binh, 2020; Trang et al., 2015). In addition to pollution from traffic, air pollution in Hanoi also originates from construction activities because the city is still in the stage of development and urbanisation at a high rate.

To self-protect from air pollution, pedestrians often use face masks when walking. A study by Tang et al. (2020) showed a high rate of wearing masks (51.25%) among pedestrians. However, that rate was only high in rush hours (67%) and dropped to 35% in non-rush hours. Besides, due to the availability and price, the majority of people were only wearing cotton/cloth type face masks that are not as effective as medical or industrial grade masks and respirators in preventing the impact of air pollution (Tang et al., 2020). In recent years, the proportion of pedestrians wearing masks has increased significantly after the outbreak of the covid pandemic due to both the request from the government and the self-consciousness of the people.

3.6.3 Noise pollution

Noise pollution in urban areas has been globally recognized as a major health concern because it could lead to various health problems including loss of hearing, sleeping disorders, high blood pressure, or cognitive impairment. In Hanoi, the chaotic traffic along with the increasing number of vehicles suggest a high level of noise pollution, which may affect the experience of pedestrians on the road. According to the Institute of Occupational Health and the Environment, to frequent horn sounds Vietnam, are facing excessive noise (Nguyen, 2017). Measuring 12 major streets and junctions in Hanoi, they found that the average noise level during the day is 77.8 to 78.1 dBA (the

specified sound level of noise), exceeding the allowable standard from 7.8 to 8.1 dBA while the average noise level at night is 65.3-75.7 dBA, being 10-20 dBA above the standard (Nguyen, 2017). Also confirmed the high level of noise in Hanoi with the daily average noise levels were more than 69 dBA, and the pattern of noise with a decrease in background noise levels at night (Phan, Yano, Sato, & Nishimura, 2010b). The noise exposure levels were also found to be positively associated with the percentage of highly annoyed participants (Phan et al., 2010a).

Using vehicle horns is a frequent behaviour in Hanoi (see figure 36), to the point it becomes a habit (VOV Traffic, 2017). 68% of motorcycle riders in Hanoi use their horn when driving and 83% of them considered horn usage as a means of safety (Phan et al., 2008). Drivers and riders use horns not only to warn but also to gain right-of-way, to urge the person in front to go faster, to overtake, to indicate their arrival or simply to relieve stress and anger in traffic jams (VOV Traffic, 2017). Phan et al. (2010b) measured noise pollution at 8 different types of streets across Hanoi and found that horns contribute up to 12% of the total noise. Horns have significant psychological impacts, creating annoyance to the Hanoi citizens (Phan et al., 2008).

3.7 Summary

Over a thousand years of history, the urban form of Hanoi has undergone many transformations and fluctuations, leaving many layers and pieces that now blend together. There are five typical urban typologies, namely the Ancient Quarter, French Quarter, Collective Living Quarters, Urbanized Villages, and New Urban Areas. These urban typologies differ in terms of their history, formation, purpose, characteristics, and current status. The city's urban transport is also unique among developing countries, with the dominance of private motor vehicles over public transport, especially motorcycles. Characteristic weather patterns alongside air and noise pollution driven by transport mode shares make the promotion of walking challenging. Under such circumstances, it is important to investigate the prevalence of walking across the city and explore how urban typologies, transport conditions, weather, and air and noise pollution affect walking behaviour, so this information can inform sustainable urban design strategies and policies.

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CHAPTER 4 METHODS

4.1 Introduction

Chapter 4 describes the methods used in this PhD research. The first section of the chapter discusses the research approaches, methods framework, the structure of the involved sub-studies and how these methods can overcome the limitations highlighted in the literature review. The second section focuses on the sampling process, site selection and pilot study. The following sections describe in detail the methods used in each sub-study.

4.2 Research approaches and methodological frameworks

4.2.1 Research approaches to overcome limitations identified in the literature

As discussed in Chapter 2, walkability is a multidisciplinary research field that requires a multidimensional approach. While perceived measures can provide data on perceptions and experiences of the built environment related to walking, they often lack objectivity and face issues of reliability (Kim, Park, & Lee, 2014). Conversely, studies employing objective measures often fall short in capturing the richness of individuals' perceptions and experiences, which are important to link those objective physical conditions and actual walking behaviours (Ewing, Handy, Brownson, Clemente, & Winston, 2006). Few studies have simultaneously assessed perceptions of the walking environment and objectively measured environmental factors related to walking. (Boehmer, Hoehner, Wyrwich, Ramirez, & Brownson, 2006; McGinn, Evenson, Herring, Huston, & Rodriguez, 2007; Moran et al., 2017; Moudon et al., 2007). Also, several studies have reported poor or moderate agreement between perceived and objectively measured walking environments (Ball et al., 2008; Gebel, Bauman, & Owen, 2009; Gebel, Bauman, Sugiyama, & Owen, 2011; Koohsari et al., 2015; McCormack, Cerin, Leslie, Du Toit, & Owen, 2008). To address this gap in the literature, the present research uses a multidimensional approach that incorporates both objective measures and perceived measures of walking and urban design to examine their relationships. Secondly, although micro-scale elements of urban design have been proven to influence walking behaviour (Sallis et al., 2015), studies on micro-scale environments are still limited compared to macro-scale ones. In addition, Chapter 2 has highlighted that a micro-scale urban research approach is often preferential over a macro-scale approach in low- and middle-income countries like Vietnam due to several reasons. Therefore, this research

focuses on the micro-scale features when assessing the urban design related to walking. Thirdly, to overcome the underreporting of walking in the literature, this research set out several strategies including: (i) redefining different elements of walking such as trips, purposes, durations and locations to effortlessly quantify those elements (ii) designing a responsive walking survey using the "stop" algorithm to maximise the ability to capture the prevalence of walking; (iii) transferring the survey to an electronic platform, integrate mapping functions, and deploy the survey on tablets, to enhance the process of survey and minimise errors in data. Those approaches will be explained in detail in the methods sections for each sub-study. The literature review also raised the problem of quantity and quality when the majority of walkability research only focuses on increasing the urban design elements that are positively associated with walking and ultimately, increasing the rate of walking. Studies focusing on the quality of urban design with the aim to enhance the quality of walking are scarce in the literature. To overcome this limitation, sub-study 3 of this research focuses on the qualities of urban design that directly influence the walking experience. In addition, sub-study 4 will assess environmental elements such as temperature, humidity, and air and noise pollution to see if they have any impacts that may change the quality of walking activities. Finally, the selection of Hanoi, the capital of Vietnam, as the case study contributes significantly to the literature on the field of urban design and walking where the studies from low-and-middle income countries in Asia are almost nonexistent. Figures 4-1 illustrates those approaches discussed above.

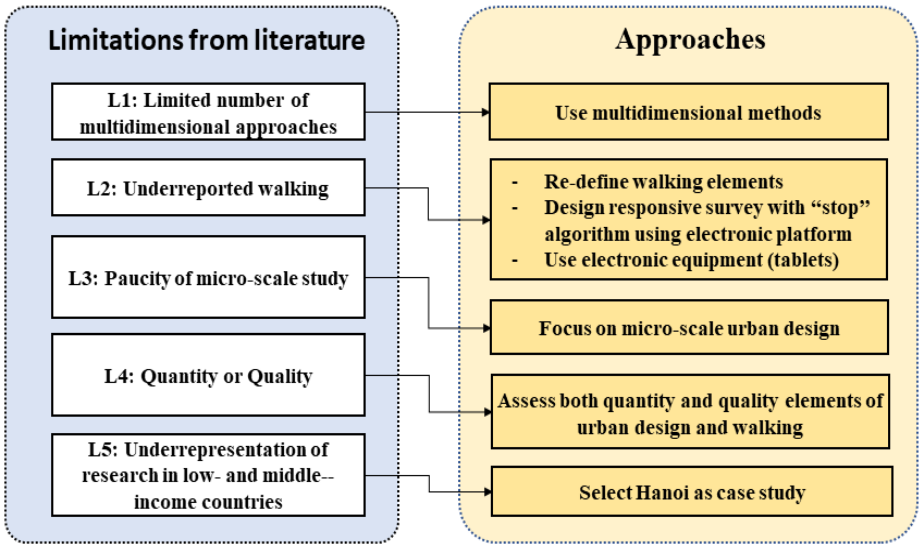

Figure 4-1 Research approaches to overcome the limitations from literature

4.2.2 Research methodological frameworks and sub-studies

The research sets out a methodological framework which includes several instruments such as the travel survey, the walking survey, the perceived urban design survey, the urban design qualities audit, the Walk Score study, and the weather and pollution audit. The methodological framework is illustrated in Figure 4-2 below:

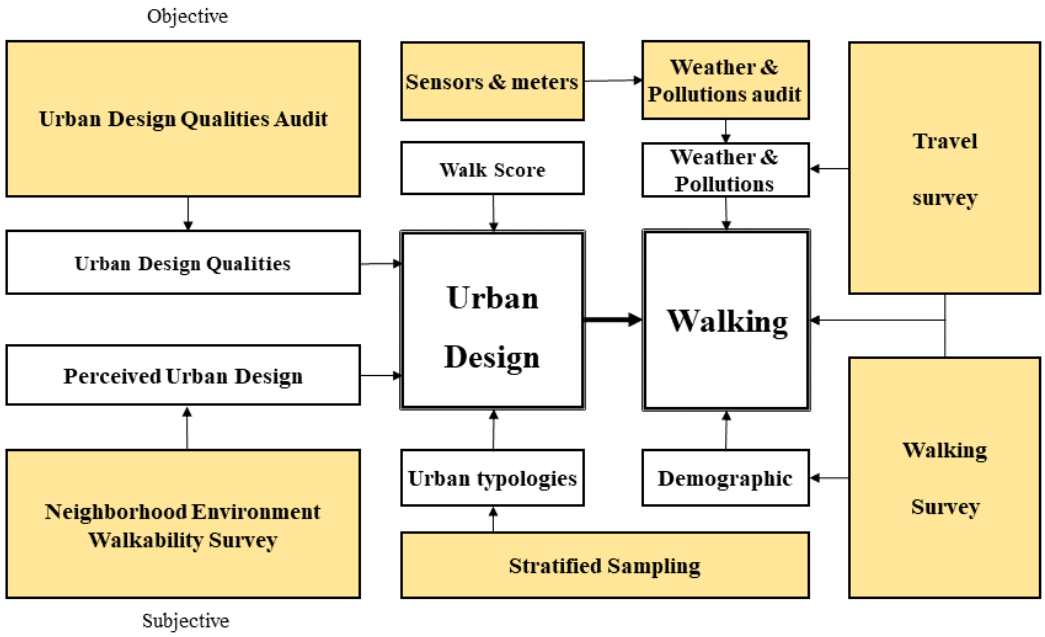

Figure 4-2 Methodological framework

Those methods correspond to the research objectives established in Chapter 1. Together, they form four sub-studies namely: (i) prevalence and characteristics of walking; (ii) perceived urban design and walking; (iii) urban design qualities and walking (iv) environmental factors and walking. Figure 4-3 illustrates the connections between research objectives, methods, and sub-studies. This chapter describes the methods of all sub-studies while chapter 5 describes and discusses the findings of Sub-study 1. Chapter 6 describes and discusses the findings of Sub-study 2 and Chapter 7 describes and discusses the findings of Sub-study 3 and 4.

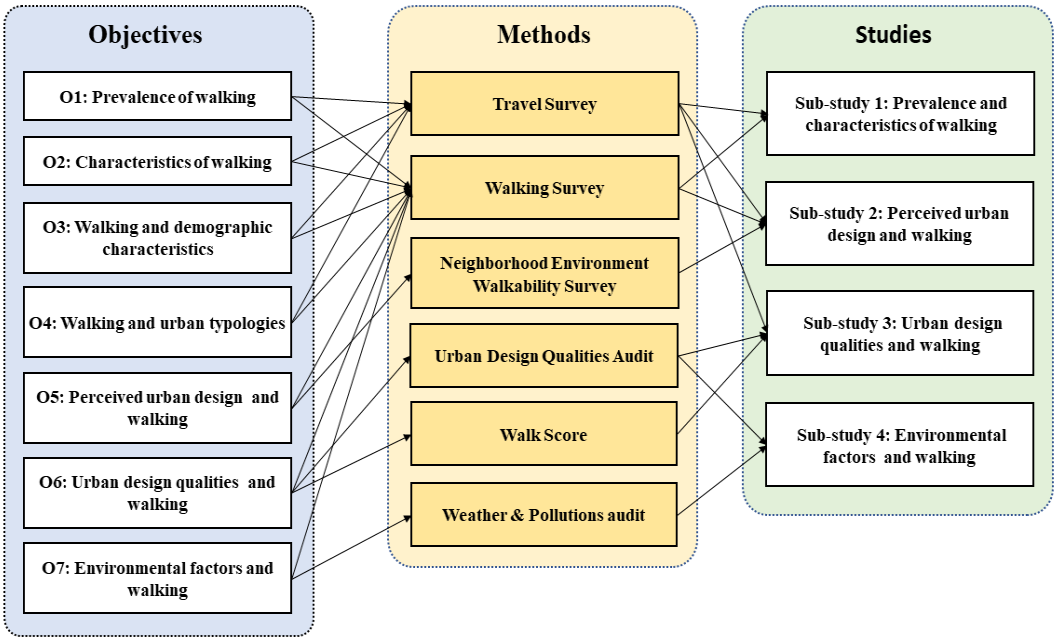

Figure 4-3 Connections between research objectives, methods, and sub-studies

4.3 Methods of Sub-study 1

4.3.1 Research design.

The main objective of Sub-study 1 is to explore the prevalence, variation, and characteristics of walking across urban typologies in Hanoi. Therefore, a cross-sectional travel survey with a focus on walking has been selected and conducted. As discussed in Chapter 2, traditional travel surveys in general and walking surveys had various limitations that often lead to the underreporting of walking. To overcome this issue, the present study redesigned the traditional travel survey and adapted it to the conditions of Hanoi.

4.3.1.1 Recall period

As discussed in Chapter 2, many researchers have highlighted that the accuracy of the walking data collected through surveys can be compromised when participants rely on recall to complete travel diaries and there is extended time between the day of activities and the day of the recall report (Shiffman, Stone, & Hufford, 2008). To obtain accurate data, it is essential to collect responses as temporally close as possible to when trips take place (Wieters, 2016). Multi-day diaries place too much burden on participants in both completing and reviewing the responses to recall interviews (Stopher, Greaves, & Clifford, 2007). There is also the possibility of no significant differences in travel being found between multi consecutive days to warrant the additional collection of data

(Stecher, Bricka, & Goldenberg, 1996). Researchers are even concerned about the drop-off in reporting due on the second or third day of the diary because participants feel less interested to report on very similar travel for two or more days (Stecher et al., 1996). For the above reasons, the recall period for the survey in the present research has been set to one day prior to the interview.

4.3.1.2 Re-defining elements of walking.

The quality of the survey data, including the accuracy and the completeness, are influenced largely by the way researchers define each included variable. The present research redefined or clarified some of the typical elements in a travel survey. These clarifications are set out below.

4.3.1.2.1 Walking

Walking in this study only is defined as a moving activity of the body that requires one leg always stays on the ground when while the other is swinging. and does not include any forms of running or racewalking. This research only focuses on walking that happens in public outdoor environments such as streets, roads, sidewalks, footpaths, parks, etc. Domestic and occupational walking at home or the workplace is not assessed.

4.3.1.2.2 Purpose

To make it easier for participants to understand and answer correctly, this survey divided trip purposes into categories such as ‘shopping’, ‘work commute’, or ‘eat a meal’ (see details in the Appendix 1). When it comes to walking, all those purposes remain the same. However, they can be grouped into two main categories: walking for transport and walking for recreation. Walking for transport can be defined as walking to reach utilitarian destinations. While the definition of walking for transport is quite straightforward, the definition of walking for recreation is sometimes problematic. Recreational walking is defined as walking for the primary purpose of fitness, health, or recreation (Hekler, Castro, Buman, & King, 2012). For some people, walking is a way to enjoy nature and the outdoors but for others, the physical and sporting aspect is more important than the enjoying part. Traditionally, walking for recreation is defined as walking that has no destination (Kang, Moudon, Hurvitz, & Saelens, 2017). For example, A person could walk around their neighbourhood or a park without any destination in mind. This definition makes it more difficult to measure and capture the characteristics of walking for recreation. Moreover, there are many cases where walking for recreation overlaps with walking for transport (Forsyth & Krizek, 2010; Gems & Pfister, 2009). For

example, people can enjoy walking to the park and consider that part as a fun and healthy exercise rather than just to transport to the park. To overcome these issues, the present research makes two important changes. Firstly, if a person walking around for recreation without a destination, we count it as two walks with the middle point of the walk being the destination for the first walking trip and the starting point for the second one. Secondly, if the person takes a walk for transport but the trip is more of a recreational trip to him/her, it would be classified as a recreational walk. For example, a trip from home to the gym can be a recreational walking trip with the purpose of sport or recreation if the walker enjoys the trip or consider that walking part as a sport activity. Otherwise, it will be a transportation trip with the purpose of 'go to the sport places'.

4.3.1.2.3 Trip, origin, destination, and mode of transport.

A trip is defined as one-way travel from point A (origin) to point B (destination) in the public outdoor environment. The 'purpose' of a trip depends on point B, the destination. Each trip has one purpose and one type of transport mode used. A walking trip has 'walking' as the transport mode. On a trip, participants can be passengers, drivers or pedestrians depending on the transport mode.

For example, if a student travels from home to school by a school bus, the travel is counted as two trips:

- Trip 1: Walk from home to the bus stop. The purpose of this trip is to 'change the mode of travel'. The transport mode is 'walking'. The origin place is home, and the destination is the bus stop. The trip start time is the moment the student leaves home and the finish time is the moment he/she arrives at the bus stop. The trip duration is the time between the start time and the finish time.
- Trip 2: Take the school bus from the bus stop to school. The purpose of this trip is to 'school commute'. The origin place is the bus stop, and the destination is the school. The transport mode is the 'school/staff bus'.

A round-trip is counted as two trips. For example, driving to the grocery store and back is counted as two trips. Trip 1 is from home to store, with the purpose of 'shopping' and the transportation mode is 'car (driver)'. Trip 2 is from store to home with the purpose of 'go home' and the transportation mode is 'car (driver)'. Another example is when people cycle around for exercise. Trip 1 is from their home to halfway point with the purpose of 'sport/exercise'. Trip 2 is from halfway point to their home with the purpose of 'go home'. The transportation mode for both trips is 'bicycle (rider)'.

4.3.1.2.4 Start time, finish time, and trip durations

The 'start time' of a trip is the moment the participants leave a place and start to travel. The finish time of a trip is the moment they arrive at their destination. The duration of the trip is the period between the start time and finish time, excluding any time spent at either origin places or the destinations.

4.3.1.3 The use of the tablet

Traditional paper-based travel surveys using travel diaries often have problems of inaccuracy and incompleteness of the data collected. Frequently found problems include errors in the times of trips reported, omission or addition of trips, and delayed completion of diary compromising recall quality (Zmud, 2006). In addition, travel diaries are labour-intensive, hence the accuracy and completeness of data are influenced largely by the effort of the participants (Wieters, 2016). To overcome those problems, the present research conducted prompted-recall interviews using electronic tablets. With touch-screen technology, the flexibility of displaying content, GPS, and the internet function of the tablets, survey software was used to optimise travel surveys by integrating interactive, adaptive, and customized questions modules. Therefore, the use of tablets not only helped to improve both the quality of the data and mechanism of data collection, but also assisted to reduce the likelihood of trip underreporting and human error, and most importantly reduced the burden of completing the survey for participants.

4.3.1.4 Questionnaire design

The questionnaire was divided into two parts. The first part was the travel survey which collects information on all trips that participants have made on the previous day. Based on the answers of participants in the first section, walking trips were filtered out and confirmed by the participants. The second part of the questionnaire - the walking survey, focuses on those walking trips with more in-depth questions.

4.3.1.4.1 The 'stop' algorithm.

The literature and pilot study suggested that participants could have many complex chain trips that consisted of multiple small trips linking together. For example, a person could come back home from the workplace, but visit a chemist on the way to buy some medicine and then visit the supermarket to buy some food before coming home. It is difficult for him/her to recall that complex sequence of trips and provide exact information about time, origin places, destinations, travel mode as well as the order of each trip. In the pilot study, most of the participants didn't understand the structure of

their chained trips, forgot a few segments of the trips, recalled trip segments in the wrong order, or had to correct answers in later interviews. To overcome these challenges, the questionnaire was re-designed with a special logic that uses stop questions. Instead of asking the number of segments in the chained trip, the participants were asked if they have made any stops during the journey and when they arrived or left those stops. A stop acts as a destination for the trip prior to it and the origin for the trip after it, and the 'arrive time' and 'leave time' act as the 'finish time' of the trip prior and the 'start time' of the trip after. A stop was only counted if it had one of the specific purposes discussed above (i.e., shopping, change travel mode). A random stop, such as a stop to take a break, was not counted. The use of this stop logic reduced the burden for participants in recalling information about their trips and assisted them to recall the structure and sequence of trips. The survey was designed in Qualtrics (qualtrics.com), an online survey platform. Take the advantage of electronic forms, the survey was designed so that it can automatically interpret those stops into required trip information in real-time. Taking the example of coming home from the workplace above, Figure 4-1 explains the sequences and other information of this chained trip with two stops: the chemist and the market. For example, the walkers recalled a stop at a chemist to buy medications and a stop at a market to buy groceries. The survey automatically breaks the come-home journey into three trips: (i) trip 1 from the workplace to the chemist with the purpose of 'shopping'; (ii) trip 2 from the chemist to the market with the purpose of 'shopping'; (iii) trip 3 from the market to home with the purpose of 'go home'. The survey also automatically interprets the arrival time and leave time at two stops into start time and finish time for those 3 trips.

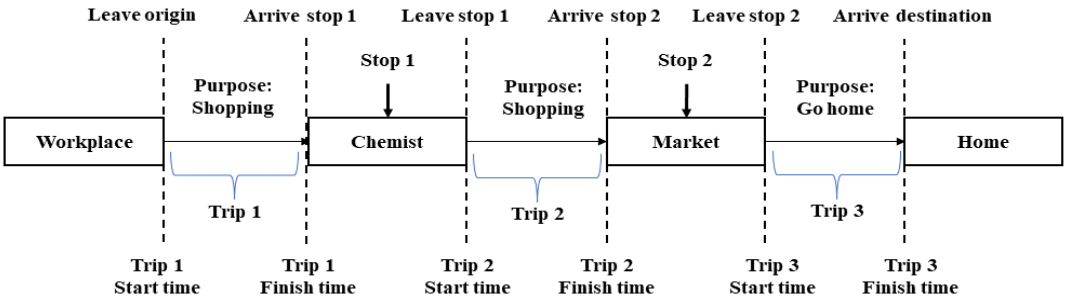

Figure 4-4 An example of how the survey record a chained trip.

4.3.1.4.2 Structure of the survey.

4.3.1.4.2.1 Travel diaries and walking trips.

Take the advantage of electronic forms, the survey was designed to be responsive to the answers of participants. The survey starts with the module of questions for the main trip including questions about the trip purpose, start time, origin place and desired destinations. Then a question about the stop was introduced: “Before reaching the destination did you make any stop?”. If the answer was ‘No’, the module of questions for the main trip continued with questions about ‘arrive time’, and mode of transport. If the answer was ‘Yes’, the module of questions for sub-trips will be introduced with the questions about the location of stops, purpose to stop, arriving time and leaving time, mode of transport etc. The module of questions for sub-trips is repeated multiple times until the answer for the question of stop is ‘No’.

The interview continued with the question about the final trip: “Did you go somewhere else after that”. If the answer was ‘No’, the travel survey will complete. If the answer was ‘Yes’, the module of questions for the main trip, the question of stop and the module of questions for sub trip were introduced as per the procedure described above. The survey procedure finished when the answer question of the final trip was ‘No’. The flow chart in Figure 4-5 explains the procedure for using those modules of questions.

After all the trips were recorded, the survey automatically filtered out all the trips that had ‘walking’ as a mode of transport. A list of walking trips was displayed to the participants to confirm. A module of questions for the walking trip was introduced to participants to obtain in-depth information about each walking trip such as detailed locations of origin and destinations, walking accompanier, reasons for selecting routes, and frequency of the trip. The location question was in the form of an interactive map that allowed participants to select locations by tapping on the map or moving the pin icon with their finger (see Figure 4-7) In case they found it hard to use the map, they could enter the address of the location, manually. If they could not remember the exact address of a location, they were able to name the nearest commonplace such as a public building, store, or supermarket, etc.

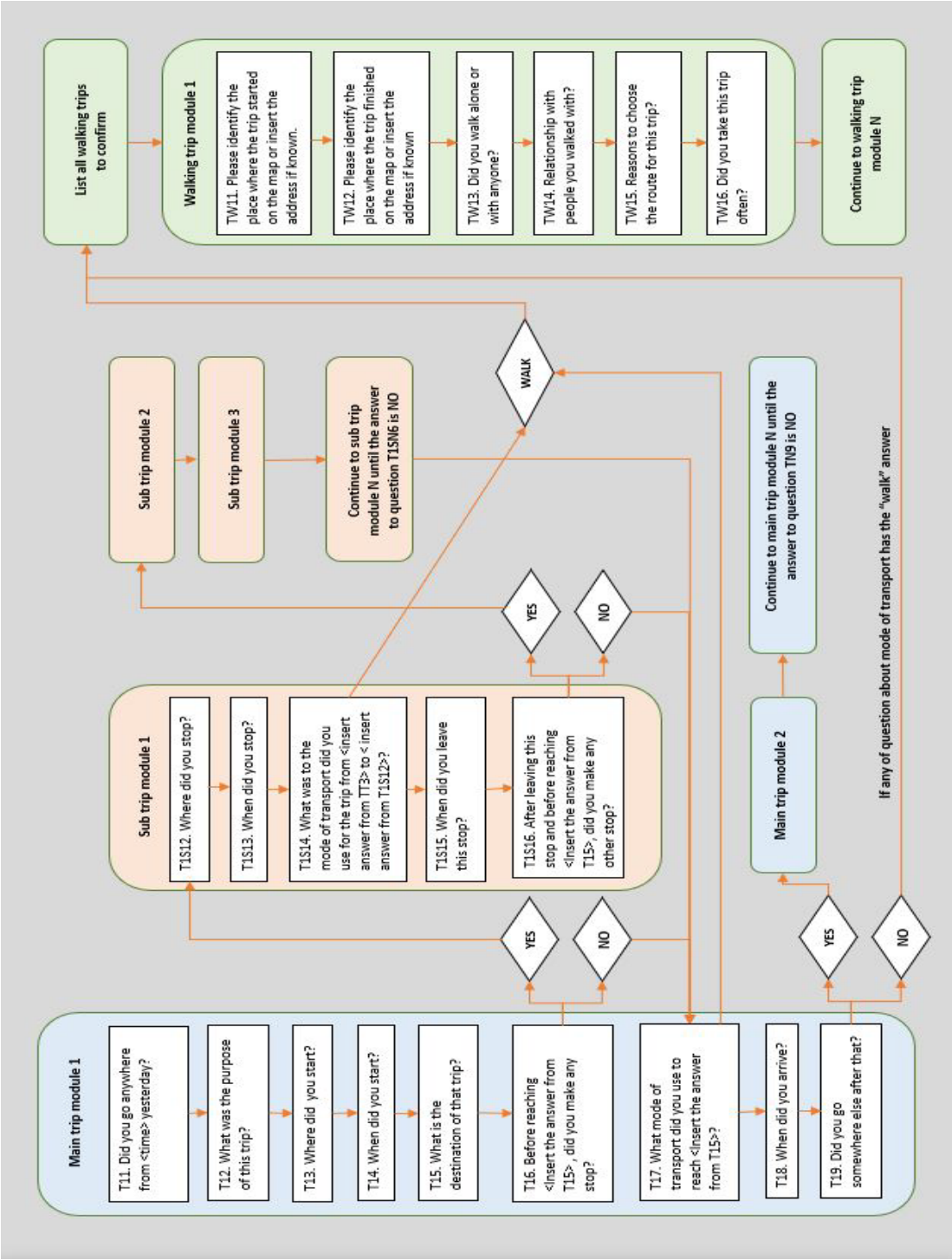

Figure 4-5 Survey procedure

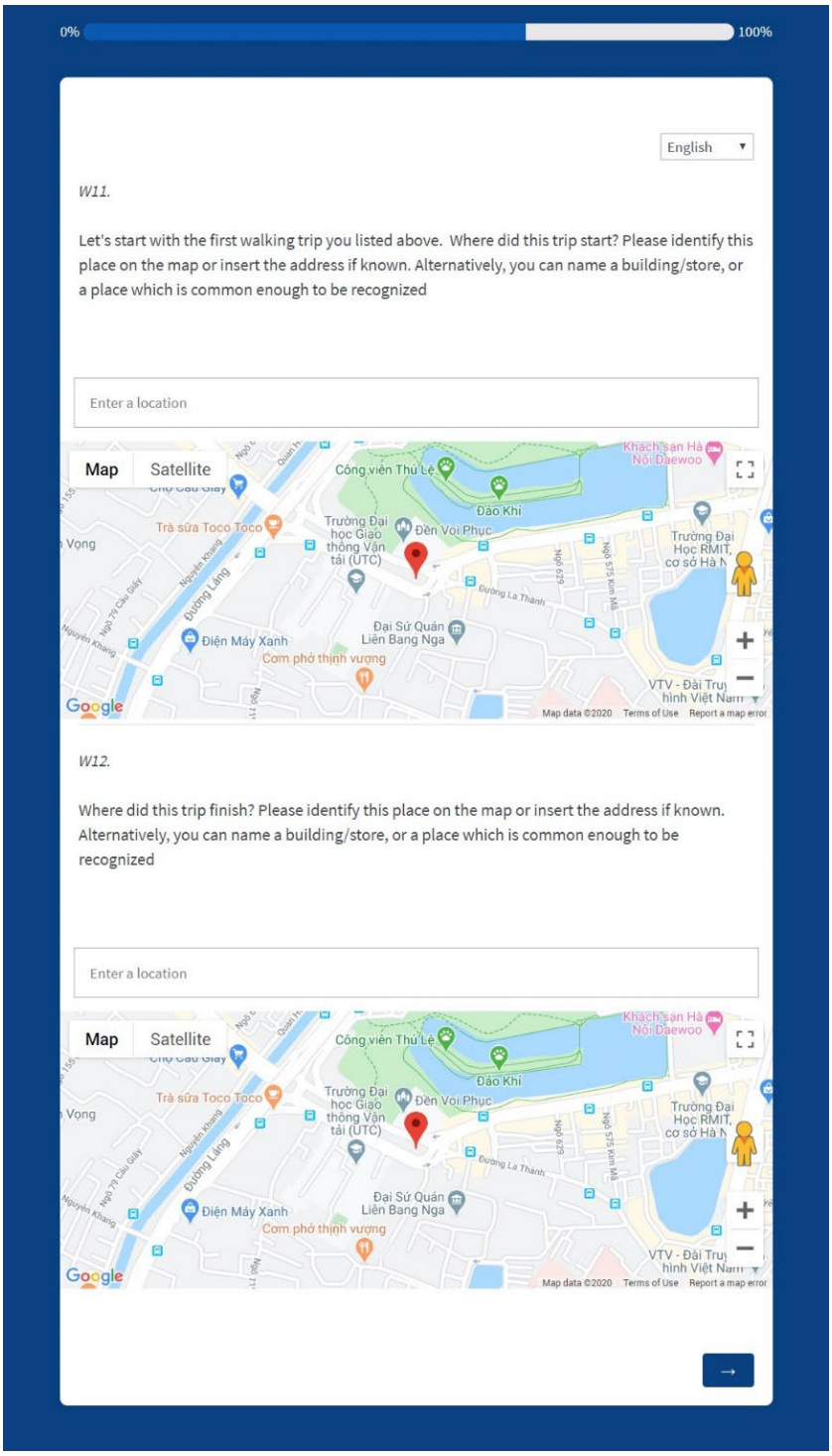

Figure 4-6 Screenshot of the survey with the interactive map

4.3.1.4.2.2 Perceived barriers and facilitators of walking

A second module within the questionnaire asked participants about perceived barriers and facilitators of walking. Based on the results of the pilot study and discussion with local experts, a list of barriers and facilitators was formed and shown to participants to select from. Participants could also give other barriers and facilitators that were not on the list.

4.3.1.4.2.3 Demographic information

The last part of the questionnaire asked questions relating to demographic information for participants. Nine socio-demographic variables were selected: age, gender, marital status, education level, employment status, body mass index (BMI) (obtained through questions of height and weight), household size, children in the household, and motorised vehicle ownership. Although participants' income was considered for inclusion, the pilot study showed that most participants were reluctant to disclose income and/or made false reports about their income levels. Income level is considered a very sensitive topic in an oriental culture like Vietnam. Considering this and the potential of unreliable data related to income, the present research therefore Omitted questions related to income. Prior studies also found no independent effect of income on walking behaviour (Leslie et al. 2007), which may be due to strong collinearity between vehicle ownership, education level, occupation, and income. This suggests that income may be important, but that asking questions related to income directly, is perhaps not the best means of assessing income levels.

4.3.2 Pilot study

Since there are no detailed studies on walking in Hanoi, the research team opted to first conduct a pilot study to estimate the prevalence of walking as well as test and examine and refine research instruments and methods before the main study.

4.3.2.1 Location and recruitment

The pilot study was conducted in Melbourne. Although urban design in Melbourne differs significantly from Hanoi, the city has a considerable number of Vietnamese communities including Vietnamese immigrants and international students who speak Vietnamese and keep a typical Vietnamese culture and lifestyle. Advertisement of the pilot study was posted on online groups of Vietnamese communities looking to recruit 20 participants with the conditions that they had previously lived in Hanoi. Participation in the study was voluntary and anonymous.

4.3.2.2 Purpose of the pilot study

The primary purpose of the pilot study was to test the length and comprehension of the survey instrument. Participants were interviewed to assess their understanding of the words in the questionnaire, clarity of each item, and to obtain suggestions for improvement. Participants were also asked if any questions made them feel uncomfortable and if any items were missing that they deemed important. All participants

were encouraged to verbalize their thought processes while providing responses to the items. The second purpose of the pilot test was to explore the prevalence of walking within a Vietnamese community. This assisted to estimate the required sample size for the study in Hanoi. The pilot study data were not used in the main study.

4.3.2.3 Results of the pilot study

For purpose of testing the survey instruments, various problems were identified in the pilot study. The first problem was the order of 'time' questions and 'location' questions, which confused some participants and led to mistakes between two trips being made (i.e., mistaking the arrival time of the previous trip and the start time of the next trip). Another problem was the use of some particular terms in the survey. Some words were reported to be difficult to understand and required a further explanation from the interviewer. The length of the survey was also identified as too long, creating a burden on participants' time and reducing their willingness to participate. Questions on levels of income were also found to be sensitive and most participants were reluctant to disclose income and/or made false reports about their income levels

Results from this pilot test led to modifications if these identified issues. The order of questions about trip times was adjusted to correspond and distinguish between trips and their stops. Complex or specialised words and terminologies were replaced by plain ones where possible, and explanations were added when necessary. The questions on income were removed. The survey was also reduced in duration by including skip logic and breaks between sections. In total, 20 participants completed the pilot study, reporting a total of 217 trips on the day before the interview. A total of 91 walking trips were completed (Mean (μ) = 4.55 per person, Standard Deviation (σ) = 3.5).

4.3.3 The context of five urban typologies

As highlighted in Chapter 3, Hanoi has five typical urban typologies, namely the Ancient Quarter, the French Quarter, the Collective Housing Quarter, the New Urban Area, and the Urbanised Village Area. The Ancient Quarter, initially comprising 36 commercial guild streets, was established in the 11th century during the feudal periods and since then it has become the centre of Hanoi. The Ancient Quarter is characterized by ancient architectural heritage including temples, pagodas, and ancient traditional shophouses. Having narrow streets and sidewalks, The Ancient Quarter features a dense street network with a high intersection density and the road–area ratio is up to 23.5% (Kato & Nguyen, 2010). The acceleration of western foreign influences started with the

French colonization (1873-1954), resulting in the establishment of the French Quarter (Geertman, 2007). The French colonial style of architecture and planning was expressed through various buildings, mansions, villas and landscape spaces like parks and lakes along with a grid-like street network of wide avenues and sidewalks. After independence from French colonization in 1957, Vietnam followed socialism taking the design from the USSR as a model (Geertman, 2007). From the 1960s, models of Soviet-style collective neighbourhoods were constructed across Hanoi. These neighbourhoods, often called Collective Housing Quarters or "KTT" in Vietnamese, were designed to accommodate 7,000 to 12,000 inhabitants and formulated by typical four to five-storied residential apartment buildings as the core structure and public facilities such as parks, community courtyards, schools, kindergartens, and markets. From 1965 to 1975, many parts of Hanoi were destroyed due to the war and rebuilt. Although the process of transforming villages, especially those near the city centre, into urban settlements has been happening for many decades, the most rapid urbanization in Hanoi only happened when the economic reform, the Doi Moi was initiated in Vietnam in 1986. Without planning and infrastructure development, many villages have been urbanised rapidly to meet the demand for housing during the period of economic growth; this urban typology is referred to as the Urbanised Village Area. These areas are characterized by the dominance of self-built houses and organic road networks consisting of many narrow, long and winding streets that were informally set up and connected based on the former village streets. Since the 1990s, new residential projects have been planned and implemented across Hanoi, resulting in various New Urban Areas. These areas feature modern housing typologies including high-rise apartments and large detached houses, along with a high standard of public services including new transportation networks (JICA, 2007). The characteristics of these five urban typologies are summarized in Figure 1, and their distribution of typologies across Hanoi is illustrated in Figure 4-7.

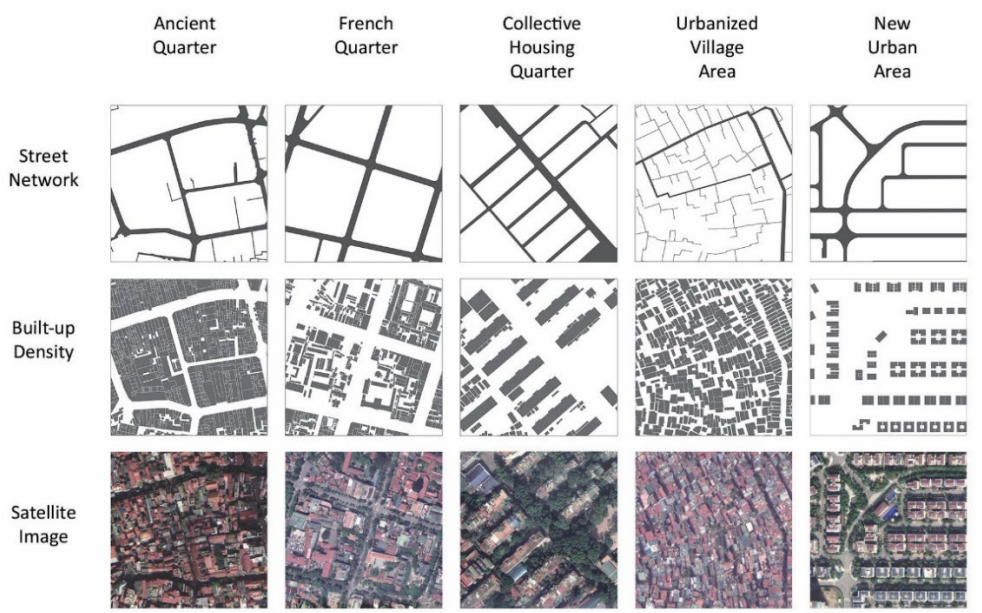

Figure 4-7 Characteristics of five urban typologies

4.3.4 Sampling

4.3.4.1 Sample size

The survey is cross-sectional to estimate the amount of walking of Hanoi's citizens, so the below formula is applied to calculate the sample size:

$$n = \frac{Z_{1-\alpha/2}{}^2 \sigma^2}{d^2}$$

n - sample size.

$Z_{1-\alpha/2}$ - Z score from the standard normal distribution.

σ - the standard deviation

d - precision or margin of error

α - the error (α = 1 – CL with CL is the Confidence Level)

The confidence level is set at 95% (at type 1 error of 5%) so $Z_{1-\alpha/2}$ = 1.96 according to the table of z-values for confidence intervals. The precision is set at 0.5. Because there isn't a previous study on walking in Hanoi, the standard deviation is obtained from the pilot study which was 3.5. Therefore, the required sample size is:

$$n = \frac{1.96^2 \times 3.5^2}{0.5^2} = 188.2$$

To increase the accuracy of results and prepare for some unusable data, the present study set a sample size of >= 200.

4.3.4.2 Sampling process

The sampling uses both stratified sampling and multi-stage cluster sampling to ensure randomness and enhance the representativeness of the sample. Excluding all rural communes, all urban wards in Hanoi were stratified into 5 groups based on their urban identified typologies: (i)Ancient Quarters; (ii) French Quarters; (iii) Collective Living Quarters (iv) Urbanized Villages (f) New Urban Areas. Figure 4-7 illustrates the characteristics of those urban typologies. In the second stage, two wards were randomly selected in each group to have 10 wards (See Figure 4-8). After creating the list of streets in these 10 wards, four streets were randomly selected in each ward to make a total of 40 streets. Finally, houses that share the same selected street were numbered and 6 numbers were randomly selected. Research team then approached the selected houses and one member of the household living on the house was invited to participate in the research. If all the household's members of selected houses refused to participate, other houses on the street would be randomly selected and approached until there were 5 to 6 consented participants on each street. Eligibility criteria for choosing participants included: (i) being current residents of Hanoi; (ii) being residents of the Hanoi area for at least 6 months; (iii) being able and willing to answer questions in Vietnamese, which is the official language in the study region; (v) not having any disability that prevented independent walking; (vi) no visible signs of cognitive impairment; (vii) must be 18 years of age or older.

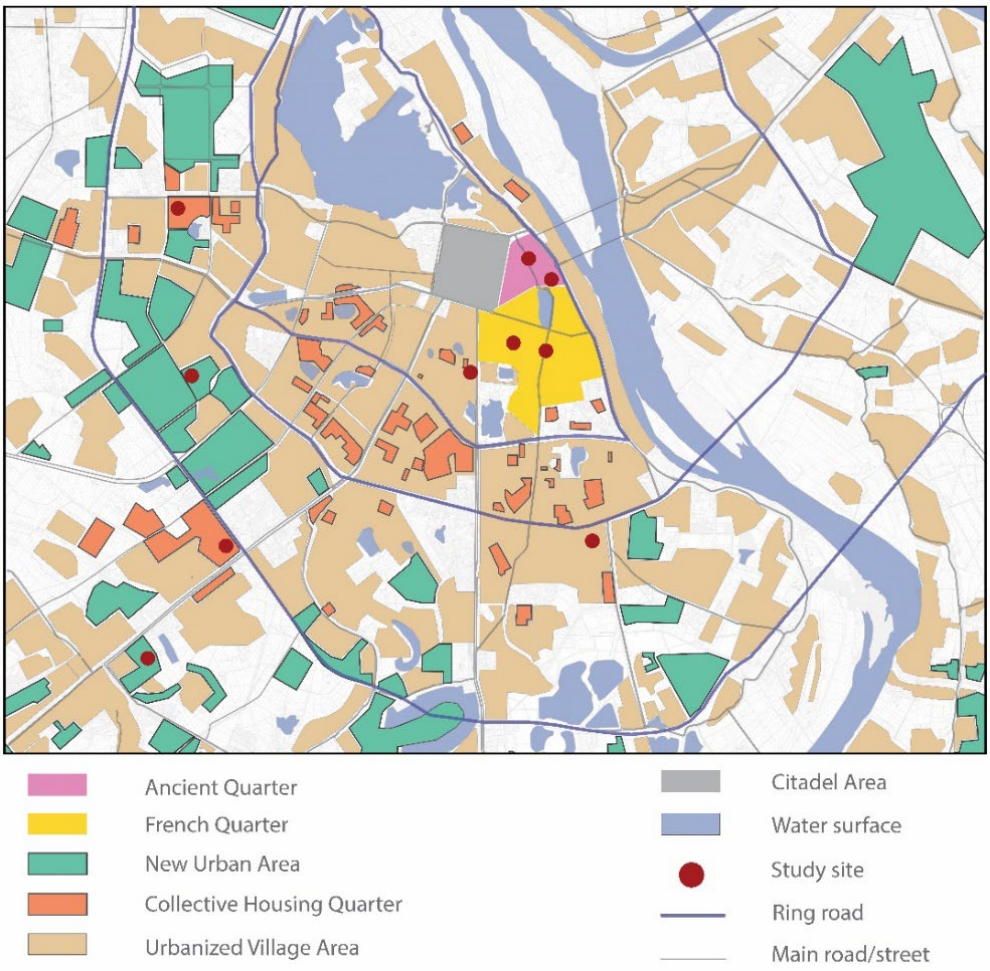

Figure 4-8 Distribution of the five urban typologies and study sites

4.3.5 Data collection.

The research team conducted the travel survey at the participants' homes by conducting 40-minute face-to-face interviews. 218 participants were recruited following the sampling strategy discussed above. Information on the researcher and the purpose of the research were provided verbally as well as in writing to participants through a Plain Language Statement (PLS). The researcher interviewed only people that gave their informed consent to participate. Participants could choose to participate in the interview in a private room with a closed door or even at a place outside their home since some might have privacy concerns when answering about their travel diary in front of other household members (see Figure 4-8).

Figure 4-9 Interviewing a participant on the sidewalk

During the interview, participants were free to skip any questions and they could exit the interview at any stage if they wished to. Participants could seek assistance from other household members in answering questions when necessary. All the questions were displayed on the tablets and answers were inserted by the participants or by the interviewer if the participants preferred this way. Upon completion, all the answers were uploaded directly to the Qualtrics server, which was accessible through a password-protected log-in. The data were then downloaded and stored on a password-protected laptop and backed up on a password-protected hard drive and cloud storage account.

All the survey materials including the questionnaire, plain language statement, consent form as well as the procedure to interview and collect data have been reviewed and approved by the Human Research Ethics Committee of the University of Melbourne (Ethics ID: 1954948 and date of approval: 19 July 2019).

4.3.6 Descriptive analysis

Descriptive analysis was used to summarise and describe the prevalence of walking by mode share, the number of trips, walking times and distance. The present study also presented and compared the quantity of walking by demographic characteristics of participants such as age, gender, occupation, marital status, BMI, and other household factors. Characteristics of walking include purposes, origin and destination, duration and distance, accompanier, route selection, and walking frequency were analysed through amount and percentage. Plus, perceived personal barriers and facilitators for walking were listed and ranked.

4.3.7 Statical analysis

To explore the associations between walking and the urban typologies where participants live as well as the demographic characteristics of the participants, the total recalled walking time all day and the average walking time per trip were chosen as outcome variables to enter regression models. The calculated on-map walking time and walking distance on the map were not selected because they were based on the fastest route and standard walking speed that may not reflect real behaviour. To make clearer the influence of urban typologies, the total walking time all day and the average walking time were divided into 2 types: walking that happened everywhere and walking that happened only inside the neighbourhood. Therefore, four dependent variables were created: 1) total walking time, 2) total walking time inside each neighbourhood, 3) average walking time per trip, and 4) average walking time per trip inside each neighbourhood. Using the normality tests (Kolmogorov-Smirnov Test and Shapiro-Wilk Test), all four variables showed positively skewed distributions (see table 4-1 and figure 4-10)

Table 4-1 Normality test for walking times

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total walking time	.132	215	**<.001**	.904	215	**<.001**
Total walking time inside the neighbourhood	.117	215	**<.001**	.890	215	**<.001**
Average walking time per trip	.119	215	**<.001**	.900	215	**<.001**
Average walking time per trip inside the neighbourhood	.108	215	**<.001**	.906	215	**<.001**

The bold value represents the data significantly (<0.05) deviate from a normal distribution

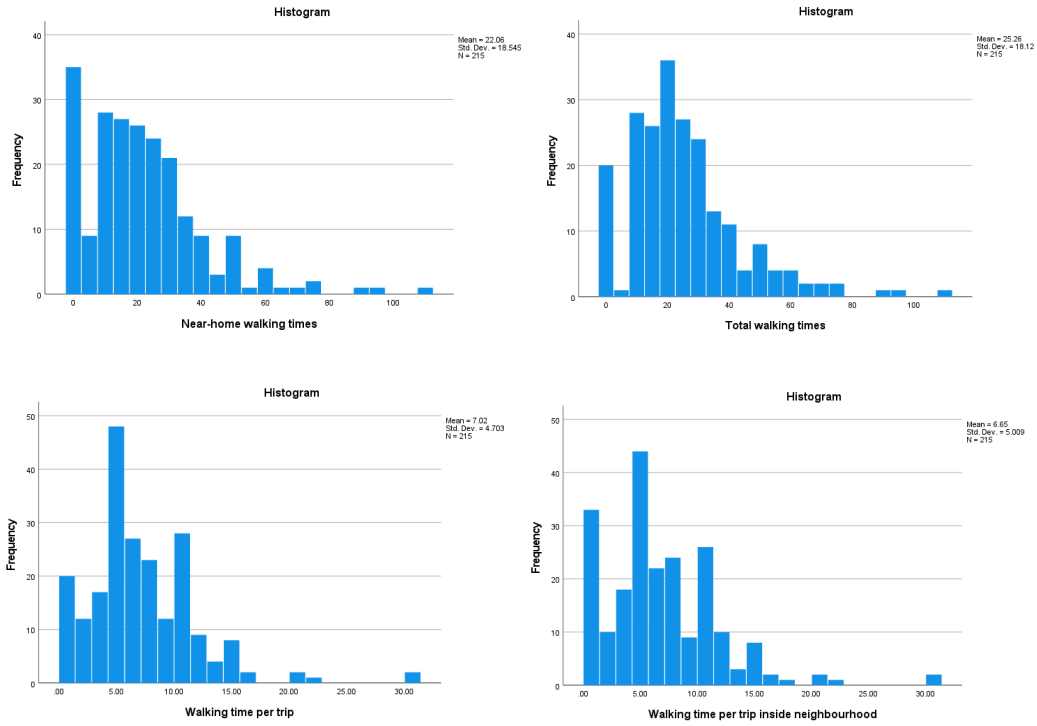

Figure 4-10 Histogram of data distribution for total walking times, walking time inside the neighbourhood, walking time per trip, and walking time per trip inside the neighbourhood

These four outcome variables also have a substantive proportion of zero values (about 10%) which were genuine zeros that may be due to two causes: (i) the participants never engage in walking, or (ii) they did not walk at all on the previous day. To deal with skewed semicontinuous outcome variables with many true zero values, two-part models are often recommended (Boulton & Williford, 2018; Lee, Zhao, Yau, & Xiang, 2010). Two-part models involve two processes: the first one determines whether an individual will have a zero versus nonzero value for an outcome, and the second process determines associations between the outcome variables with independent variables if individuals experience any amount of the outcome. These two processes are in line with the objectives of the present research which are to estimate the prevalence of walking and to explore the relationship between walking and demographic characteristic as well as urban typologies. Hence, the present research selected the two-part model to analyse walking data. Logistic regression was adopted in the first part to determine whether a participant engages in walking or not with provided predictors. In this logistic regression mode, the dependent variable which measures the willingness to engage in walking was coded as 1 when the participant has any amount of walking, and 0 otherwise. In the second part, after excluding all zero values, the four selected outcome variables still have right-skewed

distributions. Popular methods to address the non-normal distribution of data to meet statistical requirements of tests of comparison between groups include transforming the data to a better approximate normal distribution using logarithmic, square root, or inverse transformations (Osborne, 2010). However, non-negative continuous variables like walking time are often not able to be transformed to restore normality. Further, transformed values also lose their original scale, making the process of interpretation more difficult (Baldwin, Fellingham, & Baldwin, 2016).

To avoid those issues, the generalized linear model is often recommended (Boulton & Williford, 2018; Ng & Cribbie, 2017). The present research selected the generalized linear model with a log link function and gamma response distribution in part of the two-part models. In the end, there was a total of six models: two logistic regression models to determine the probability of walking in general and inside the neighbourhood, and four generalized linear models to determine the association between independent variables and total walking time and average walking time per trip in general and inside the neighbourhood.

Models that dealt with walking in general only used demographic variables while models that dealt with walking inside the neighbourhood added the variable of urban typologies. Categorical independent variables such as gender, education level, marital status, occupational status, vehicle ownership, children in the household, and urban typologies were dummy coded to enter the regression.

4.4 Methods of Sub-study 2

4.4.1 Perceived urban design measure.

4.4.1.1 The NEWS-A

The perception of urban design for physical activity such as walking was assessed using the NEWS-A instrument. NEWS (also called the San Diego instrument) is a 98-question instrument developed by Saelens, Sallis, Black, and Chen (2003) to assess the perception of neighbourhood design features believed to be related to physical activity. The NEWS questionnaire has an abbreviated version (NEWS-A) with 54 items which achieves the same as the extended NEWS. They have been adapted and translated into various languages and found to be reliable and valid in many countries (Arvidsson, Kawakami, Ohlsson, & Sundquist, 2012; Cerin, Leslie, Owen, & Bauman, 2008; Cerin et al., 2010; Hallal et al., 2010; Sheu-jen, Wen-chi, Patricia, & Jackson, 2010; Stopher et al., 2007). The NEWS-A questionnaire assessed several environmental characteristics grouped into 8 main subscales and 4 single items as follows:

1. Residential density
2. Land use mix (Land use diversity)
3. Access to services
4. Street connectivity
5. Walking facilities
6. Aesthetics
7. Pedestrian traffic safety
8. Crime Safety

Four single items:

- Lack of parking
- Absence of cul-de-sacs
- Hilliness
- Physical barriers

All items, except for the residential density and land use mix subscales, are assessed using a 4-point Likert scale from 1 (strongly disagree) to 4 (strongly agree). Residential density items are assessed on a 5-point Likert scale and weighted relative to the proportion of various types of residences, from single-family detached homes to high-rise apartments with a numerical response ranging from 1 (none) to 5 (all). Land use mix is rated by the walking distance in minutes (from 1-5 minutes to more than 30 minutes) to various types of

businesses or facilities such as stores, restaurants, and post offices. In most items, a higher score suggests a better environment for walking. However, for some items, like those in traffic safety and crime safety, the subscales have inversed scores, which means a higher score means a reduced likelihood of walking in the environment. The overall score of each subscale is the means of scores of items belonging to this subscale. As mentioned above, since the tool was developed in the US, an adaption process is required to apply it to the context of Hanoi. The adapted version was named NEWS-A Vietnamese (NEWS-A-V).

4.4.1.2 Instrument adaption

4.4.1.2.1 Modifications

A multi-disciplinary panel of experts from the fields of urban design (n = 2), urban planning (n = 1), and transportation (n=1) reviewed the original English version to discuss how to adapt them to reflect the built environment of Hanoi. A number of original items were modified or removed while new items that were relevant to the study setting and target population, were added. Although the guidelines from IPEN recommended retaining as many as possible original items even if they do not exist in a target country, the panel of experts agreed to remove or modify items (n=2) that were not relevant to the context of Hanoi. All modifications are presented in Table 4-2. Furthermore, to enhance participants' understanding of concepts, photos and/or illustrations were added in some items such as 'Residential density' to ensure that participants could understand the types of residences in the question.

Table 4-2 Adaptation of NEW-A-V

Modified items	Reason
Changed 'townhouses or row houses of 1-3 stories' to 'townhouses or row houses	The number of stories of townhouses and row houses varies greatly in Hanoi
Changed destination 'supermarket' to 'supermarket/big market' and 'vegetable market' to 'vegetable market/small market'	To specify the destination because markets/small markets are common destinations in Hanoi
Changed destination 'video store' was changed to 'Internet/gaming cafe'.	Video stores have no longer existed while internet/gaming cafes are popular entertainment destinations in Hanoi
Changed destination 'recreation centre' to 'Sports centre/Football fields/swimming pools.	To specify the destination because playing football and swimming are popular recreational activities in Hanoi

Modified items	Reason
Change item 'Sidewalks are separated from the road/traffic in my neighbourhood by parked cars' to 'There is a painted line that separates the sidewalks from parking spaces'	The painted line to mark the parking area is common on sidewalks in Hanoi
Change '30 Mph' to '50 Kph' and '100 yards' to '100 metres'	The Metric system is used in Vietnam
Changed single items 'The streets in my neighbourhood do not have many cul-de-sacs (dead-end streets)' to 'My neighbourhood does not have many dead-end streets' and moved to the 'Street Connectivity' subscale	Cul-de-sacs is uncommon in Hanoi
Moved two single items 'Parking is difficult in local shopping areas' and 'There are major barriers to walking in my local area that make it hard to get from place to place' to the 'Access to Services' subscale	As suggested by the expert panel and to match the original NEWS
Removed items	
Removed item 'There is a grass/dirt strip that separates the streets from the sidewalks in my neighbourhood	Grass/dirt strip is uncommon in Hanoi
Removed single items 'The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in.'	Hanoi has relatively flat terrain
Added items	
Added destination 'Religious places'	Religious places such as pagodas or churches are common destinations in Hanoi
Added item 'The sidewalks in my neighbourhood are well maintained' to 'Walking Facilities' subscale	The poorly maintained sidewalk is a common issue in Hanoi
Added item 'Sidewalks in my neighbourhood are often encroached or obstructed by parked vehicles, sidewalk businesses, vendors, or physical obstructions' to 'Walking facilities' subscale	Sidewalk encroachment is common in Hanoi

4.4.1.2.2 Translation

The modified version was forward-translated to Vietnamese by a bilingual person that was fluent in both Vietnamese and English, and back-translated to English by another bilingual person for review. The research team independently reviewed the quality of both translated versions and discussed any detected issues. Changes to words and the structure of sentences were made due to the difference between the two languages. The process of translation was repeated until a final agreement was reached so that the translated version was identical in meaning to the original one and all questions and concepts in the questionnaire could be understood by residents residing in Hanoi.

4.4.1.2.3 A pilot study of NEWS-A-V

The pilot of the NEWS-A-V questionnaire was integrated into the pilot of Sub-study 1 described in section 4.3.2 of this Chapter. Participants in the pilot study were asked if there were any questions that they did not understand, they felt unsuitable, or made them uncomfortable answering. They were also asked if they had suggestions to improve the questionnaire. All participants were encouraged to verbalize any concerns they had whilst completing the questionnaire. Participants' feedback was discussed with the research team and a number of items (n=8) were rephrased and reformatted.

4.4.1.2.4 Transferring the questionnaire to an electronic form

Using the survey development platform Qualtrics (Qualtrics.com), the final version of the NEWS-A-V questionnaire was transferred to an electronic form suitable to administer NEWS-A-V on tablets thereby reducing the burden of completing the interview for interviewers and participants via a paper-based version. The survey could be switched between two languages English and Vietnamese. Furthermore, the completed interviews could be directly and securely uploaded to a Qualtrics online server ready to be analysed. Figure 4-11 shows a sample of the questions displayed on the tablet screen.

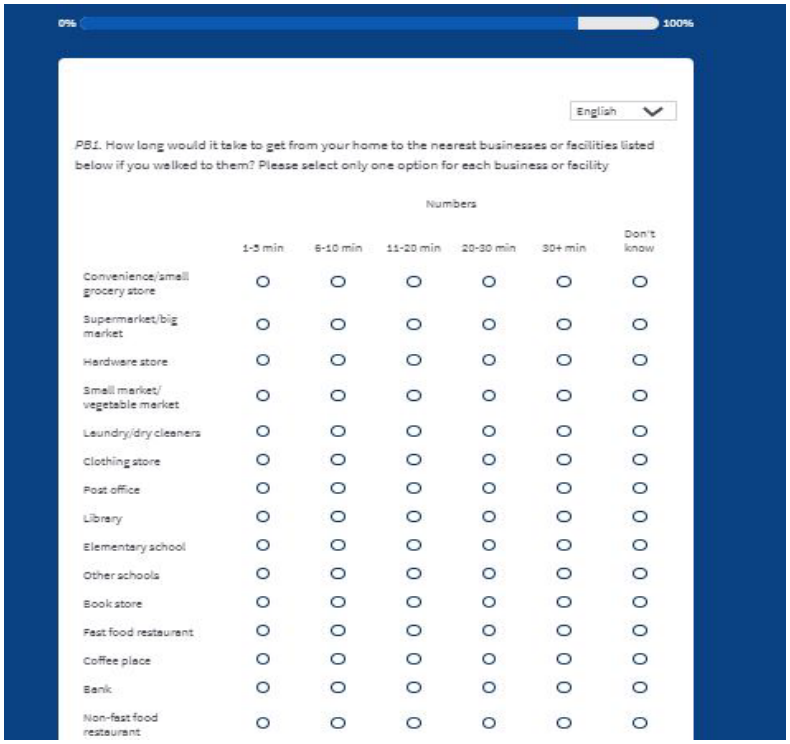

Figure 4-11 Screenshot of a multi-choice question in the perceived urban design survey.

4.4.2 Walking data

Walking data were obtained through the walking survey from Sub-study 1. As Sub-study 2 describes the perceived urban design of the surrounding neighbourhood and its association with walking, the number of walking trips inside the neighbourhood (describe in Chapter 5) was used as the outcome variable described in the results in Chapter 5

4.4.3 Sampling & data collection

Sub-study 2 use the same sample as Sub-study 1 and the perceived urban design survey was conducted after the walking survey in the same appointment with the participants. The sampling and the data collection process was described in section 4.3.3 and 4.34 in this Chapter. A total of 215 participants were recruited from various neighbourhoods representing one of five typical urban typologies (43 participants per urban typology) in Hanoi namely, the Ancient Quarter, French Quarter, Collective Housing Quarters, Urbanised Village Areas, and New Urban Areas. All participants were asked whether they would be willing to be re-interviewed again later for testing the reliability of the questionnaire. Forty-eight participants agreed and participated in a second interview. The interval between the two interviews ranged from 14 to 18 days (an average of 16 days).

4.4.4 Data Analysis

4.4.4.1 Test-retest reliability

To evaluate the test-retest reliability of the adapted NEWS-A-V, intraclass correlation coefficients (ICC) with a 95% confidence interval were calculated for individual items and eight subscales. ICC values which were > 0.5, ICC between 0.5 to 0.75, ICC from 0.75 to 0.9, and a ICC < 0.90 were indicative of poor, moderate, good, and excellent reliability, respectively (Koo & Li, 2016). The ICC of eight subscales from NEWS-A-V were also compared with the original NEWS and other versions of NEWS and NEWS-A.

4.4.4.2 Descriptive analysis

Descriptive statistics of perceived urban design scores for individual items and the eight subscales were calculated. Items having inverse effects were adjusted so that higher scores denoted higher walkability. The combined subscale scores were compared between demographic characteristics and the five typical urban design typologies of Hanoi namely the Ancient Quarter, French Quarter, Collective Housing Quarter,

Urbanised Village Area, and New Urban Area (see Chapter 3 for more details of these urban typologies). The mean combined scores of eight subscales for five urban typologies were also Z-scored and then visualised in a box plot chart for comparison.

4.4.4.3 Statistical analysis

Multiple linear regressions were applied to determine the relationship between the participants' perceived urban design and the five urban typologies. The five urban typologies were dummy coded and entered the regression analyses with the New Urban Area as the reference category. To assess the association between the perceived urban design characteristics and walking, the number of walking trips undertaken inside the respective neighbourhoods was the dependent variable. Using the normality tests (Kolmogorov-Smirnov Test and Shapiro-Wilk Test), the number of walking trips inside the neighbourhood was found to have a positively skewed distribution (see Figure 4-12). Furthermore, the number of walking trips variable had a substantive proportion of zero values (32 out of 215) which might be due to (i) the participants never engaging in walking or (ii) they only happened to not walk on the previous day of the survey. To deal with skewed count outcome data with many zero values, Zero-inflated Poisson Regression (ZIP) or Zero-inflated Negative Binomial Regression (ZINB) are often recommended (Washington, Karlaftis, Mannering, & Anastasopoulos, 2020). ZIP was chosen over ZINB to analyse the data in this study due to it having a lower calculated Akaike information criterion (AIC) than ZINB ($\Delta = 2$) which suggests a better fit (Burnham & Anderson, 2004). ZIP simultaneously estimates two separate statistical models: a logit model to estimate the covariates that predict the probability of walking (zero trip and non-zero trip), and a Poisson regression model to predict the number of walking trips. The ZIP model was adjusted by age, gender, and educational level. Statistical significance was considered to be present when $P < 0.05$. All analyses were conducted by using SPSS version 28.0 for Windows with the R-essential add-in.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	p.	Statistic	df	Sig.
Walking trips inside the neighbourhood	.144	215	<.001	.943	215	<.001

a. Lilliefors Significance Correction

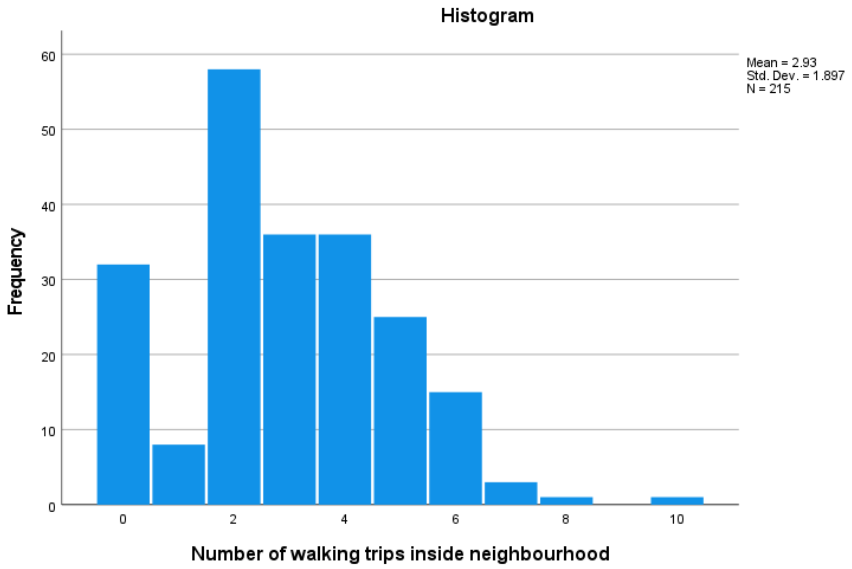

Figure 4-12 Test of normality and histogram of distribution for the number of walking trips

4.5 Methods of Sub-study 3 and Sub-study 4

4.5.1 Instruments.

4.5.1.1 Urban design qualities measure

To assess the urban design qualities of the five urban typologies, we adapted the urban design quality measurement tool developed by Ewing et al. (2006). They proposed a conceptual framework explaining the process of how the physical features of the environment are perceived by people. The physical features of urban spaces create the urban design qualities which are perceived differently by varied users and lead to their own perceptions and reactions. Based on the framework by Ewing and Handy, the procedures to measure urban design qualities of the walking environment, have been made more transferable and easier to measure objectively. They did this by relating physical features of urban design qualities to five urban design qualities (imageability, enclosure, human scale, transparency and complexity) and then validated the features (an established tool) in New York (Ewing & Clemente, 2013; Ewing & Handy, 2009). They described five urban design qualities namely:

- *Imageability* which is the quality of a place that leaves distinct, recognisable, and memorable images in the minds of people. Features of high imageability spaces include physical elements that can capture, create, and evoke emotions. The elements measured are the number of people on the street, the proportion of historic buildings, courtyards, plazas, parks, and outdoor dining areas.
- *Enclosure* is the degree to which streets have a room-like feeling, defined by vertical elements such as buildings, walls, trees, and other vertical elements. The tool records the number of long sight lines, the proportion of street walls and the proportion of sky view to determine the enclosure level.
- *Human scale* is the proportion of physical elements' size, texture, and articulation that match the human form and correspond to people's walking speed. The elements that influence the quality of human scale quality include the height and length of buildings, the proportion of windows, on-street furniture, and small planters
- *Transparency* refers to the level of human activity that can be seen and perceived beyond the edge of the street or public space. The proportion of windows, street walls and the level of active use of the space are factors that affect the transparency of a street.
- *Complexity* is the level of the visual richness of a street. The variety of physical elements, specifically the numbers and types of buildings, ornaments, landscape features, and human activity, contribute to the complexity of a street.

To apply the tool in Hanoi, we amended the tool with respect to a number of definitions. For example, the definition of "historic buildings", which is determined to be "pre-WWII" in the original version, was changed to be "pre-1954" in the adapted version according to the definition of historic mansions and buildings from the Hanoi Municipal People's Committee. As well, the level of noise in the original tool is subjectively measured by the perception of the researcher in the field on a scale of five points. To overcome this limitation of subjectiveness, we objectively measured the level of noise at each location using a smartphone app; the U.S. National Institute for Occupational Safety and Health (NIOSH) Sound Level Meter (SLM) developed by NIOSH. the We classified the recorded levels of noise into five categories based on the scale derived by The American Academy of Audiology namely: i) very quiet: under 30dB, ii) quiet: from 30

dB to 50 dB, iii) normal: from 50 dB to 70 dB, iv) loud: from 70 dB to 90 dB, and v) very loud: above 90 dB.

4.5.1.2 Walk Score

The Walk Score, an online walkability index (available at walkscore.com), calculates the walkability of locations with a score from 0 to 100, based on the distance from a location to nearby amenities (Walkscore). Maximum points are awarded for amenities within a 5-minute walk (.25 miles). More distant amenities up to 30 minutes away are given points using a decay function. This score is also adjusted by population density and two street network measures (block length and intersection density). The Walk Score is free, easy to use, and has comparability between locations. However, it's criticised for not including other assessments of the built environment such as pedestrian facilities, street design, aesthetics, and safety from crime and traffic (Nykiforuk, McGetrick, Crick, & Johnson, 2016). Higher scores often only mean that the location has more local destinations nearby. Due to the mixed-use characteristic of many Asian cities, such cities typically generate high Walk Scores (Leather, Fabian, Gota, & Mejia, 2011). Sub-study 3 examines the association between the Walk Score and the prevalence of walking as well as urban design qualities in Hanoi.

4.5.1.3 Environmental factors (temperature, humidity, air and noise pollution).

As highlighted in Chapter 3, environmental factors namely, temperature and humidity, along with air and noise pollution affect the experience of pedestrians in Hanoi. To collect the necessary data, portable sensors were deployed at 40 selected streets across Hanoi. The Wi-Fi Weather Station (Ecowitt model no. GW1100) was used to collect weather data including temperature and humidity. The weather station sensor has a temperature range from -10°C to 60°C (14°F - 140°F) and a temperature resolution of 0.1°C (0.1°F). The wireless $PM_{2.5}$ air quality sensor (Ecowitt model no. WH41) was used to measure the level of $PM_{2.5}$ and convert it to the AQI index. For the $PM_{2.5}$ air quality sensor, the manufacturer specified accuracy of +/- 15% at 25 ºC +/- 5 ºC, with a resolution of 1 µg/m3. The noise data was recorded as the equivalent continuous sound pressure level (LAeq) which is the constant noise level that would result in the same total sound energy being produced over a given period.

4.5.2 Sampling.

Sub-studies 3 and 4 used the same sampling process as Sub-study 1 described in section 4.3.3 of this Chapter. However, the same sampling process for Sub-study 3 and 4

stopped at the stage of selection of 40 streets across Hanoi (8 streets representing each urban typology).

4.5.3 Data collection

Urban design qualities data were collected using the fieldwork manual developed by Ewing and Clemente (2013). Once the various elements of the urban design quality were observed and recorded, specific multipliers along with constants derived from models developed by the tool developers (Ewing & Clemente, 2013) were applied to obtain the scores for the urban design qualities. Specific details on the application and derivation of the tool can be found in Ewing and Clemente's paper (Ewing & Clemente, 2013).

A team of two researchers visited the selected streets on weekdays only; the same day that interviews in Sub-study 1 and Sub-study 2 were carried out. For each selected street, observations were undertaken along a distance of 100 meters. For streets in which there were multiple 100-meter segments, the team selected the most central part of the street The research assistants measured all variables comprising the five urban design qualities and counted pedestrians along the selected 100-meter segments, strictly adhering to the fieldwork manual (Ewing & Clemente, 2013) which included prescribed measurements. To summarise, it involved the researcher, at a given time point, counting people visible in a 100m segment of the street along with counting people at the cross street to the observed site. This was repeated at four-time intervals and the average number of pedestrians was documented. For further detail on the approach please refer to the fieldwork manual (Ewing & Clemente, 2013). All observations/measurements were attained over a one-hour period in each street.

On the same 40 selected streets, the participants in Sub-study 1 and Sub-study 2 were asked for permission to install the sensors on the outside of their houses. The $PM_{2.5}$ air quality sensors were installed at a height of at least 1m in front of the consenting participants' houses on each selected street and above ground level (see Figure 4-13). The Wi-Fi Weather Stations were installed in a position that was located between the air quality sensor and the Wi-Fi signal source of the hosting household to ensure the connection to the Ecowitt online server for uploading the data. Data of temperature, humidity, and $PM_{2.5}$ could be monitored in real-time and downloaded from the Ecowitt server. The noise pollution data was collected along with the noise part of the Urban

Design Quality audit, using the smartphone app The NIOSH Sound Level Meter (SLM) developed by the U.S. National Institute for Occupational Safety and Health (NIOSH)

Figure 4-13 The $PM_{2.5}$ sensor is installed on the gate of a house on the street.

4.5.4 Data analysis

Descriptive statistics were calculated across the five urban design qualities and the total urban design quality score for each urban typology. The mean scores of the individual and total combined urban design qualities for five urban typologies were standardised for comparative purposes using a Z-score. The mean scores of individual and total combined urban design qualities attained for Hanoi were compared with studies that used the same measurement tool. The three comparative cities are New York, USA (Ewing & Clemente, 2013), Brisbane, Australia (Hooi & Pojani, 2020) and Gurgaon, India (Khetrapal & Chadchan, 2019). The mean value of the Walk Score, temperature, humidity, level of air pollution (PM2.5) and the level of noise pollution (LAeq) were calculated for each urban typology. Multiple linear regression was also undertaken to determine whether the various urban design qualities were associated with the respective urban typology. Urban typologies were dummy coded to enter the regressions with the urban typology -'Urbanised Village Area' as the reference category. This urban typology was selected as the reference category as it is the most common typology of the five urban typologies in Hanoi. Simple linear regressions were conducted to assess the association between the number of pedestrians and the total urban design qualities score, Walks Scores, temperature, humidity, level of air pollution ($PM_{2.5}$) and level of noise pollution

(LAeq). Multiple linear regression was also undertaken to investigate the associations between the Walk Score and the urban design qualities. All analyses were conducted using SPSS version 28.0 for Windows.

4.6 Chapter summary.

Chapter 4 summarises the research approaches to overcome the limitations identified in the literature and the methodological frameworks to meet the set-out research objectives. Chapter 4 also describes in detail the methods for all four sub-studies including the process of sampling, site selection, instruments adaptation, data collection as well as data analysis. Chapters 5, 6 and 7 will describe and discuss the finding of the sub-studies and refer to Chapter 4 where necessary for factors related to methods.

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CHAPTER 5 PREVALENCE AND CHARACTERISTICS OF WALKING

5.1 Introduction

As reviewed in Chapter 2, there is a growing body of literature highlighting the significant benefits that walking brings to urban citizens. Walking, as the most basic and accessible form of physical activity, encourages healthier communities and reduces the rate of non-communicable diseases (NCDs) such as cardiovascular disease and type 2 diabetes (Lee & Buchner, 2008). Apart from health benefits, there are also social, environmental, and economic benefits of walking (Brand et al., 2021; Litman, 2017). Despite the potential co-benefits associated with walking in urban areas, the advent of rapid motorisation and urbanisation, which are associated with private motor vehicle use and car-oriented urban and transport planning, has led to a degraded pedestrian environment(Forsyth & Southworth, 2008; Shay, Spoon, & Khattak, 2004). Walking has declined significantly in the United States, Western European countries and Australia in the past four decades (Pucher & Buehler, 2010). In Asian low and middle-income countries, although walking still acts as a key mode of transport in many developing countries throughout Asia because of its affordability, cities are losing their traditional walking lifestyle (Leather, Fabian, Gota, & Mejia, 2011) and instead, are embracing rapid urban development in which the focus of urban planning is oriented toward private motor vehicles. Consistent with this pattern, Vietnam has been experiencing a rapid pace of urbanisation and growth of private motorised vehicles, accompanied by environmental deterioration, intensified traffic congestion and increased physical inactivity (Nguyen & Trevisan, 2020). A global study (Althoff et al., 2017) ranked Vietnam among the most sedentary countries in the world on daily steps. More than 28% of adults obtained sufficient physical activity (General Office of Population and Family Planning, 2010), contributing to many health burdens such as increasing deaths from non-communicable disease (from 44.07% in 1976 to 73.41% in 2015). In Hanoi, the capital and one of the largest cities of Vietnam, walking mode share has declined dramatically, from 50 per cent of all trips in 1995 to 25 per cent of all trips in 2005 (JICA, 2007). Consequently, it is important to study the situation of walking in Vietnamese cities so that this issue can be better understood and addressed.

Chapter 5 describes Sub-study 1 which explores the prevalence and characteristics of urban walking in Hanoi. Variations of walking rates associated with demographic

factors and urban typologies across Hanoi are analysed. Finally, perceived facilitators and barriers to walking in Hanoi are identified and discussed.

5.2 Methods

Methods for this study (Sub-study 1) were described in section 4.3 of Chapter 4. The five urban design typologies are Ancient Quarter, French Quarter, Collective Housing Quarters, Urbanised Village Areas, and New Urban Areas. These urban design typologies are identified and described in section 3.4 of Chapter 3 and section 4.3.3 of Chapter 4. Figure 5-1 illustrates the research framework and the main contents of Sub-study 1.

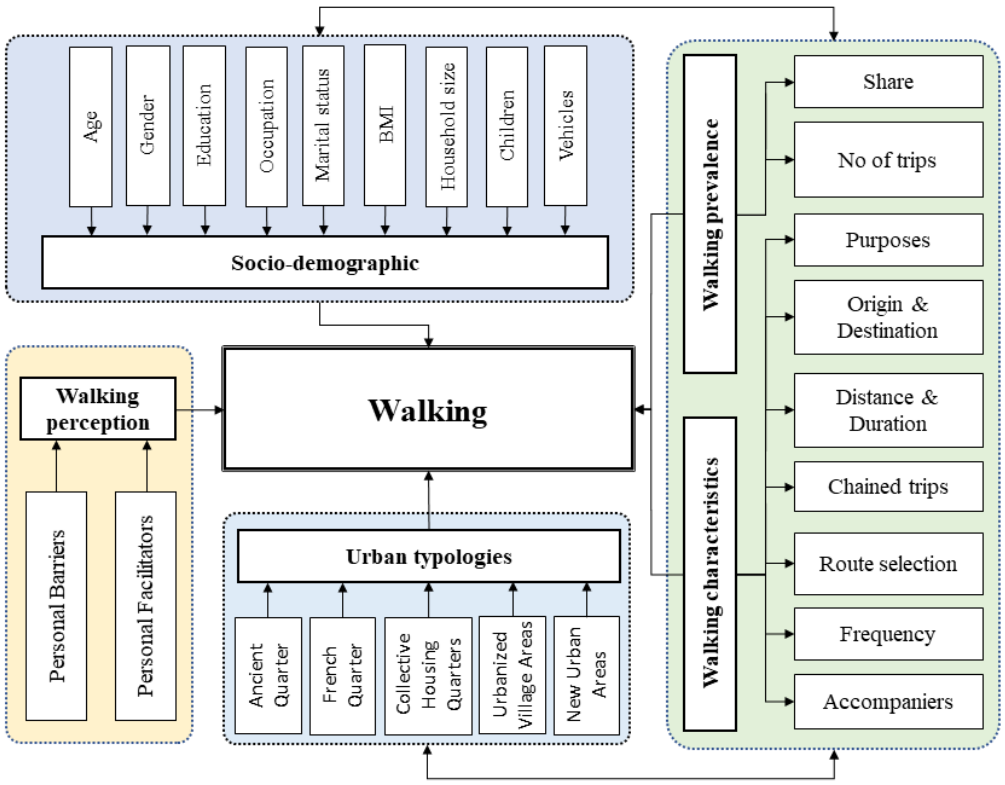

Figure 5-1 Research framework of Sub-study 1

5.3 Result and discuss

5.3.1 Transport mode share and prevalence of walking

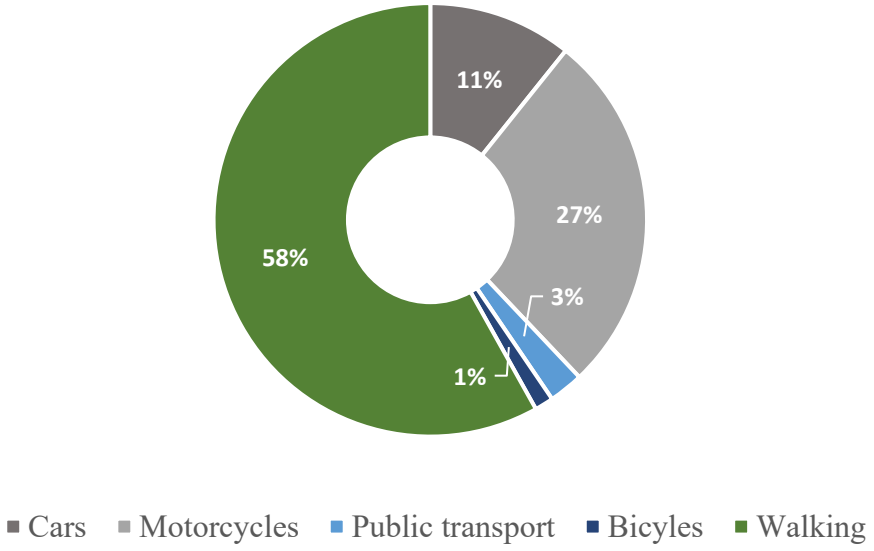

Figure 5-2 Share of number trips

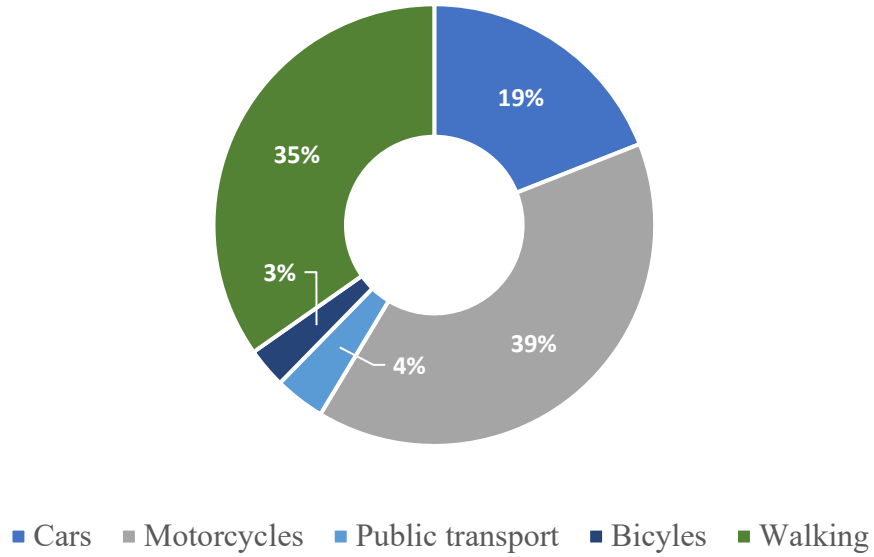

Figure 5-3 Share of travel time

Figure 5-2 and Figure 5-3 show each travel mode's share of the number of trips and time. Walking makes up 58% of the number of trips. Motorcycles and cars come in second and third positions with 27% and 11 per cent respectively, while bicycles only accounted for 1% of the number of trips. Although walking is dominant over other modes in the share of trips, walking duration only accounts for 35 % of the share of travel time. People

spent most time travelling on motorcycles (39 %), followed by walking, cars, public transport, and bicycles.

Applying the new definition and the new method to capture walking trips, the present research shows a significantly high share of walking in terms of both the number of trips and travel duration compared with previous studies about mode share in Hanoi (JICA, 2007; Pham, 2017). The differences in the share of walking between the number of trips and walking duration can be explained by the fact that walking is dominant in short-distance trips while motorised vehicles are more suitable for long-distance trips. Research by Tran et al. (2015) showed that walking in Hanoi accounted for a mode share of 86.85% in the trip range below 0.5 km but only three per cent in the trip range over 10 km.

With the high share of walking, although motorcycles take the first position in travel time and second position in the number of trips, they are not as dominant as in other studies of urban transport in Hanoi (JICA, 2007; Pham, 2017; Tuan, 2015). As discussed in the literature review in Chapter 2, the reason may be that those studies (JICA, 2007; Pham, 2017; Tuan, 2015) tend to under-report, overlook, or exclude walking in their data collection.

Among all the transport modes, bicycles have the lowest share at only 1% for the number of trips and 3% for travel time, which is consistent with the study by Huynh and Gomez-Ibañez (2017). Up until a few decades ago, bicycles were still the dominant mode in Hanoi(Hansen, 2016; Huynh & Gomez-Ibañez, 2017; Nguyen & Pojani, 2022) with an estimated number of 600,000 bicycles in 1981 (Koh, 2006) and 1,000,000 bicycles in 1991 (Bell & Kuranami, 1994). However, after the economic reform (Doi Moi) in 1986, people gradually shifted to motorcycles, making the share of bicycles decrease significantly from more than 60% in 1995 to 25% in 2005 and just 2.5% in 2008 (Huynh & Gomez-Ibañez, 2017).

Table 4-1 shows that participants undertook most of their car and motorcycle trips as drivers. No bicycle trips are recorded as passengers. Notably, a significant number of trips by car (640 trips) and motorcycle (736 trips) are ridesharing taxi services, which is 9.6 times and 46 times higher than traditional car taxis and motorcycle taxis respectively. This reflects the rapid adoption of ridesharing services which are replacing traditional taxi services in Vietnam (Nguyen-Phuoc, Su, Tran, Le, & Johnson, 2020).

The representation of electric bicycles should also be acknowledged, although mode share is very small. Electric bicycles are popular for youths, especially students due

to their stylish designs, compact size, ease of control and operation (Thuy & Hong, 2019). At the time of the survey, the metro line of Hanoi was not yet operational, so no metro trips were recorded.

Table 5-1 also shows one of the significant features of urban transport in Hanoi which is the frequency of trip chaining with one-third of the total trips being chained trips. Trip chaining is travel that involves multiple purposes to single or multiple destinations and a chained trip is part of a chain of trips (Currie & Delbosc, 2011; Shiftan, 1998). The popularity of trip chaining in Hanoi is primarily due to the city's high density of services, giving residents more opportunities to integrate multiple destinations and purposes in their journey. For example, one can visit the market for shopping or pick up his/her child on the way returning home from the workplace. The number of chained trips is exceptionally high in bus/transit (83%), which often involves other trips to get to/from bus stops or train stations. Per centage of chained trips is also higher in motorised means of transport (56% for cars and 42% for motorcycles) than non-motorised ones (25% for bicycles and 24% for walking), which can be explained by the fact that people can reach more destinations, much longer distances and carry more passengers and things with motorised vehicles.

Table 5-1 Travel time, number of trips, number of chained trips by transport modes

Mode	Time (Minutes)	Trips	Chained trips	Per centage of chained trips
Car	2981	138	77	56%
Car (driver)	2178	99	69	70%
Car (passenger)	88	7	1	14%
Car rideshares	640	29	7	24%
Car Taxi	75	3	0	0%
Motorcycle	6208	350	147	42%
Motorcycle (driver)	5035	269	116	43%
Motorcycle (passenger)	422	34	5	15%
Motorcycle rideshares	736	46	26	57%
Motorcycle Taxi	15	1	0	0%
Bicycle	570	39	10	25%
Bicycle (driver)	460	33	10	30%
Bicycle (passenger)	0	0	0	0%
Electric bicycle	110	6	0	0%
Bus/Transit	579	18	15	83%
Bus/transit	269	10	9	90%
School/staff bus	310	8	6	75%
Walk	5430	745	178	24%
Total	25996	1829	676	33%

5.3.2 Demographic of pedestrians

Table 5-2 Number, duration, and distances of walking trips by pedestrians' characteristics.

Participants characteristics	N	%	Number of walking trips per day	Recalled walking time per day (Minutes)	Walking time on map per day (Minutes)	walking distance per day (Metres)
Age						
18-24	54	25.12%	*3.15*	*22.06*	18.74	1508.93
25-44	112	52.09%	3.54	23.53	*18.08*	*1447.44*
45-59	31	14.42%	3.19	25.26	17.13	1373.42
60+	18	8.37%	**4.44**	**46.44**	**25.94**	**2063.72**
Gender						
Male	106	49.30%	*3.38*	*22.42*	*16.66*	*1333.83*
Female	109	50.70%	**3.57**	**28.31**	**20.93**	**1678.59**
Marital Status						
Single (never married)	88	40.93%	*3.13*	*22.19*	*17.95*	*1444.72*
Married	114	53.02%	**3.74**	26.29	19.11	1527.59
Divorced/Widowed/Separated	13	6.05%	3.46	**28.13**	**21.31**	**1695.23**
Education Level						
High school or college or lower	89	41.40%	**3.52**	**27.98**	**19.92**	1595.22
University or higher	126	58.60%	*3.43*	*23.33*	*17.94*	*1437.87*
Occupation						
Employed	82	38.14%	3.39	*21.17*	*15.73*	*1260.38*
Unemployed/ Retired	28	13.02%	**4.11**	**39.86**	**24.68**	**1930.75**
Self-employed	22	10.23%	3.77	30.27	21.86	1740.82
Student	34	15.81%	*2.97*	23.03	18.03	1448.65
Household Members						
1	5	2.33%	*1.2*	*6.80*	*8.20*	*623.00*
2 - 3	93	43.26%	3.28	24.23	**19.49**	**1558.39**
4 or more	117	54.42%	**3.72**	**26.99**	18.64	1498.06
Living with Children						
Yes	123	57.21%	**3.59**	**27.26**	**19.78**	**1584.93**
No	92	42.79%	*3.32*	*22.74*	*17.41*	*1395.35*
Motorised Vehicles						
Yes	192	89.30%	*3.39*	*24.89*	*18.19*	*1514.89*
No	23	10.70%	**4.17**	**28.96**	**23.57**	**1893.39**
BMI						
<18.5 (Underweight)	2	0.93%	3.50	**42.50**	**30.50**	**2363.50**
18.5–22.99 (Normal)	133	61.86%	**4.52**	31.20	24.14	1936.03
>=23–24.99 (Overweight)	80	37.21%	*1.73*	*15.14*	*9.58*	*767.06*

Note: boldface font indicates that the maximum values, italic font indicates minimum values.

5.3.2.1 Age

On average, people from all age groups do more than 3 walking trips per day. Among all age groups, people over 60 years old walk the most with more than 4 trips and approximately 2km per day. This result seems to be contrary to studies in other countries (Berger, Der, Mutrie, & Hannah, 2005; Mesters, Wahl, & Van Keulen, 2014; Norman, Bellocco, Vaida, & Wolk, 2002) where the elderly tend to do less physical activities than the young. Multi-generation households are common in Vietnam and there is much more multigenerational interaction than is commonly seen in western families (Mestechkina, Son, & Shin, 2014). Extended family in general and grandparents in particular play an important role in helping raise children in Vietnam (Locke, Hoa, & Tam, 2012; Mestechkina et al., 2014). Therefore, old people in Hanoi may have more responsible walks such as taking or picking up their grandchildren from school or doing shopping for their families. Most of them are retired so they also have more time for recreational walking. In each neighbourhood, the elderly usually participate in community groups, clubs, unions and associations such as elderly's associations, women's unions, veterans' associations, and retirees' club which often involves various social activities in the immediate vicinity, helping to increase the walking rates among older residents. However, it should be noted that the gap between recalled walking time and on-map walking time (obtained by Google Map API) is most significant for this age group. People over 60 years old recalled spending 46.4 minutes walking per day, but the average calculated on-map walking time was only 26.5 minutes. Due to their age, older people may find it more difficult to recall the exact start time and finish time of their walking trips. Also, older people tend to walk at a slower speed and tire more quickly than young ones, which can be explained by the loss of strength and mass in leg muscles at their ages (Song & Geyer, 2018).

There are not many differences in the prevalence of walking in other age groups with slightly above three trips per day. The younger generation (18-24 years old) is the least active with only 22 minutes of walking per day. Research by Bupa (2013) in the UK showed a similar result with a quarter of those aged 18-24 walking for an average of only 5 minutes per day. Australian Sports Commission (2010) also reported young adults to have the lowest prevalence of walking. Bupa highlighted that one of the causes is today's technology. Young generations have greater social interaction online but fewer encounters in the physical environment, discouraging them from engaging in outdoor activities like walking (Bupa, 2013). Reasons can also be the negative perceptions about

walking when young people feel that walking is boring (Darker, French, Longdon, Morris, & Eves, 2007; Sabharwal, 2018) or insufficient intensity to achieve any health or fitness goals at their age (Jose, Cleland, Venn, & Hansen, 2013). Furthermore, most young adults focus on start or building up their careers therefore they often are either exhausted or don't have enough time after work/study to engage in walking. The recalled walking times in both age groups are longer than calculated walking times on Google Maps, which suggests that the walking speed is slower than the theoretical speed. The walking speed might be affected by walking environments including both negative factors (e.g. poor walking facilities with many obstructions, crowded traffic, bad weather conditions) and positive factors (e.g. vibrant and lively streets creating more opportunities for stopping or being distracted from walking). Walking in a group, chatting or using a mobile phone during the walk can also slow down the speed.

5.3.2.2 Gender & Marital status

Females in Hanoi tend to walk more than males. Their daily average number of walking trips, walking duration and distances are all higher than males. Hanoi's citizens who are single walk considerably less than married people, 3.13 and 3.74 trips respectively, which seems to be consistent with other studies (Sobal & Hanson, 2010; Zandieh, Martinez, Flacke, & van Maarseveen, 2017) Although unmarried adults reported to have more time on exercising than married adults (Nomaguchi & Bianchi, 2004), they have less household task-oriented walking than married ones, such as shopping family errands or children walking (Sobal & Hanson, 2010). However, Nomaguchi and Bianchi (2004) suggested that the marital role may only be developed into an opportunity for physical activity like walking rather than become obligations that prevent physical activity.

5.3.2.3 Employment, education, and vehicle ownership

Unemployed and retired people spent more time walking than employed or self-employed people. This is most likely due to unemployed and retired people in Hanoi having more free time than employed ones and therefore possibly doing more recreational walking. Those who walk the least are students, which is consistent with the results by age groups where young adults are the least likely to walk. In terms of educational levels, people with a university degree or higher tend to walk less than people with college and high school degrees or lower. People without motorised vehicles (car & motorcycles) spent substantially more time walking than those owning motorised vehicles. Employment,

education level, and vehicles ownership are often correlated with each other because people who had higher education are more likely to have jobs (which are usually less labour-intensive) and more likely to have private vehicles such as cars or motorcycles instead of walking or using public transport (Zang & Ng, 2016). However, in a city of motorcycles like Hanoi, the number of people owning private motorised vehicles, especially motorcycles, is significantly higher than those who don't, therefore vehicle ownership factor may not influence the prevalence of walking much.

5.3.2.4 Household structure

The more members the households have, the more walking they do. People who live in households that have four or more members walk the most with an average of 3.72 trips per day and 27 minutes, while those in two to three-member families only walk about 3.28 trips and 24.23 minutes daily. People living alone walk the least with only more than 1 trip per day. Also, households with children reported higher walking rates and times than those without children. These results might be due to support from family members/siblings leading to higher levels of physical activities (Morrissey, Janz, Letuchy, Francis, & Levy, 2015). It is also possible that a larger household size encourages more family interactions and opportunities to walk with family members. The presence of children in households may also advocate more walking trips with children such as walking them to school or the park or around the neighbourhood for recreation.

5.3.2.5 BMI

Body mass index (BMI) was calculated using the formula:

$$\text{BMI} = \text{Weight (kg)} / [\text{Height (cm)}]^2$$

Asian classifications of BMI were used, with three categories: underweight (<18.5), normal (18.5–22.9), and overweight (>23) (WHO expert consultation, 2004). The result in the table shows that people that overweight walk considerably less than people who have BMI in the normal range, with 1.73 trips per day compared to 4.52 trips per day, respectively.

5.3.3 Walking characteristics

5.3.3.1 Number, duration, and distance of walking trips

Participants reported a total number of 746 walking trips and a total walking distance of 323km, which means an average of 3.4 walking trips and 2.7 km walking distance per day per person. The average length of a walking trip is 433m. Participants recalled a total walking duration of 5445 minutes. However, according to the location of destinations and origins of the trips they selected on the map, the total walking duration calculated by Google Map API was only 4038 minutes. This difference may be due to many reasons. Since the start and end times of people's trips are self-reported, in many cases, people tend to round to the nearest 5 or 10 minutes (Rietveld, 2002). The walking duration depends on the walker's speed and the longer recalled walking times suggest that the walking speed, in reality, is slower than the theoretical speed. The walking speed might be affected by walking environments including both negative factors (e.g., poor walking facilities with many obstructions, crowded traffic, bad weather conditions) and positive factors (e.g. vibrant and lively streets creating more opportunities for stopping or being distracted from walking). Walking in a group, chatting or using a mobile phone during the walk can also slow down the speed. Also, the participants might select different routes from the fastest routes chosen by Google Maps (see figure 5-4). Reasons for choosing routes were discussed in depth in a later section of this chapter.

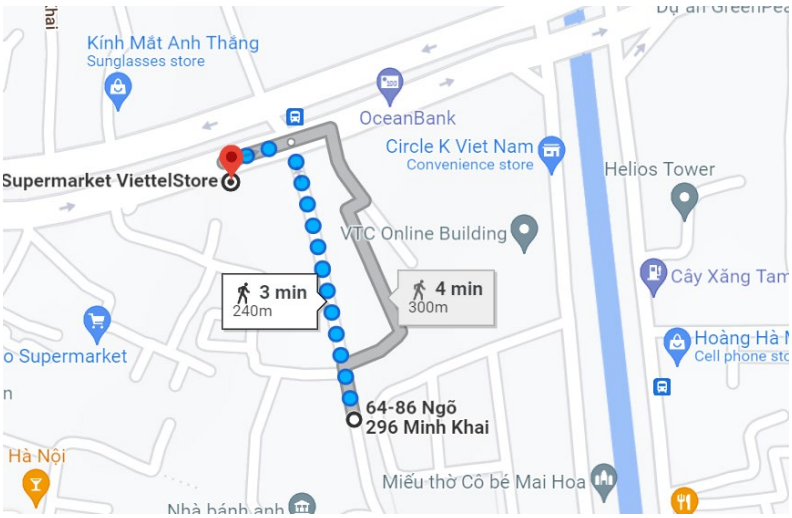

Figure 5-4 Alternative walking routes.

Source: Screenshot from Google Maps (2022)

5.3.3.2 Number, duration, and distance of walking trips

Table 5-3 Number of trips, duration and distance by walking purposes

Purpose	No of Trips	Recalled duration (minutes)	Duration on map (minutes)	Distance (metres)
Walking for transport				
Go home	243	7.83	5.63	449.83
Eat a meal	138	5.54	4.38	351.26
Change travel mode	61	5.34	3.67	294.69
Go to sports/recreation place	54	8.04	5.98	481.70
Shopping	48	7.79	5.65	454.75
Work commute	45	5.78	4.04	324.44
Accompany or transport someone	24	9.58	5.58	442.92
Personal business	19	6.74	4.63	360.79
School commute	9	6.22	7.22	588.89
Other work/business	8	10.50	3.50	284.75
Walking for recreation				
Sport/Exercise	63	9.75	8.90	716.97
Recreation	26	8.08	5.23	419.92

As explained in the method chapter, the purpose of a trip is dictated by what was done at the end of that leg therefore a chained trip can break into several trips with different purposes. Also, transportation walks can be recreational only when the participants considered so.

As seen in table 5-3, in terms of transportation walking, as expected, the most popular purpose of walking trips is 'Go home' with 243 trips since most people return to their home at the end of the day. People mostly walk for their basic life activities like eating, and sporting, therefore, other popular walking purposes include 'Eat a meal', 'Change travel mode' and "Go to sport/recreation place" with 138, 61 and 55 trips respectively. There are only 48 walking trips with the purpose of shopping. People might prefer using motorised vehicles to go shopping since they have to carry various things that they bought back home.

On the other hand, people are not likely to walk to their workplaces and schools since walking for 'work commute' and 'school commute' only came in 7th and 9th places. Walking may be part of but not the only travel mode used in achieving the final purpose/destination as shown by the high percentage of 'Change travel mode' trips. The category of 'Change Travel Mode' relates to those trip legs to change to another form of transport. This covers trips such as travel to catch public transport e.g., walking to or from the bus stop. It can also include walking back to the car parking after doing errands.

In terms of recreational walking, 'Sport/Exercise' is the most popular walking purpose with 63 trips while 'Recreation' comes in 2nd place with only 26 trips.

Table 5-4 Walking purposes by age group and gender

Purposes	18-24		25-44		45-59		60+		Male		Female	
	N	%	N	%	N	%	N	%	N	%	N	%
Walking for transport												
Go Home	55	33%	128	32%	31	31%	29	36%	116	32%	127	34%
Work Commute	5	3%	32	8%	6	6%	2	3%	30	8%	15	4%
School Commute	9	5%	0	0%	0	0%	0	0%	2	1%	7	2%
Shopping	6	4%	19	5%	11	11%	12	15%	13	4%	35	9%
Eat a Meal	32	19%	75	19%	19	19%	12	15%	73	20%	65	17%
Go to sports/recreation place	8	5%	27	7%	10	10%	9	11%	30	8%	24	6%
Accompany or transport someone	0	0%	19	5%	3	3%	2	3%	6	2%	18	5%
Change Travel Mode	24	15%	32	8%	2	2%	3	4%	33	9%	28	7%
Personal Business	4	2%	10	3%	4	4%	1	1%	7	2%	12	3%
Other Work/business	0	0%	6	2%	0	0%	2	3%	7	2%	1	0%
Walking for recreation												
Recreation	6	4%	11	3%	5	5%	4	5%	12	3%	14	4%
Sport/Exercise	15	9%	36	9%	8	8%	4	5%	35	10%	28	7%

As seen in table 5-4, differing from other age groups, people aged 60 or over age have more walking trips for 'Shopping' and 'Go to sports/recreation places'. Not having to get up early for work, the elderly in Hanoi keep up the habit of going to public spaces for exercising and then visiting the morning market on the way home to buy groceries.

As expected, 'Work Commute' walking trips are dominant in the working-age group (24- to 44-year-old). On the other hand, the 'School commute' walking trips only happen in the 18–24-year-old group since people in this age group are often students. Trip to 'Change Trave Mode' also happens mostly in this age group for the simple reason that students frequently travel by bus which often involves walking trips to/from bus stops. However, there is no trip with the purpose of 'Accompany or transport someone' for this

young age group since this purpose often includes trips such as walking children to school trips that are more popular with married people in older age groups

In terms of gender, men walk to work two times more than women (8% and 4%) but women do more shopping on foot (9%) compared to men (4%). Women also is the gender that often 'accompanies or transport someone' which is mostly in form of walking children to school. Being heavily influenced by Confucianism, Vietnamese women often take care of their children and do domestic work including grocery shopping for the family, while men are expected to work hard to support their family (An, Waling, & Bourne, 2022; Knodel, Loi, Jayakody, & Huy, 2005; Teerawichitchainan, Knodel, Vu, & Vu, 2010). Despite the prevalence of this traditional gender norm, there are more positive shifts in the perceptions of gender roles, especially in urban areas, with men being more open to sharing the burden of housework (ISDS, 2020).

5.3.3.3 Origin and Destination

Table 5-5 Origin and destination

Places	Origin	%	Destination	%
Home	263	36%	231	33%
Restaurant	58	8%	64	9%
Workplace	52	7%	45	6%
Coffee shop	52	7%	54	8%
Other recreation places	52	7%	54	8%
Sport Place	50	7%	52	7%
School	36	5%	35	5%
Park	36	5%	38	5%
Market/ Supermarket	32	4%	30	4%
Other business places	21	3%	19	3%
Friend's/ Relative's home	19	3%	18	3%
Bus stop/ Station	16	2%	18	3%
Parking	16	2%	18	3%
Shop	14	2%	15	2%
Spiritual Place	8	1%	8	1%

Table 5-5 shows that most home-based walking trips have either destination or origin is home, so it is the most popular destination and origin, followed by restaurants and workplaces. Some social/recreational places like coffee shops, sports places, and parks are also popular destinations. In Hanoi, coffee shops have become special spaces

(for both leisure and work), unique culture and an integral part of the city for generations (Zukas, 2020). People can enjoy a cup of coffee, relax by themselves, or meet, work, and develop business and social connections at coffee shops. Coffee shops are presented at every corner in Hanoi, from professional ones of coffeehouse chains to luxurious ones in the shopping centre, however, the casual cafes on the sidewalks are most popular. Similarly, Hanoi is also famous for its street food culture. There are informal food stalls and restaurants with outdoor dining on sidewalks along most streets in Hanoi, serving breakfast, lunch, dinner, and even late meals (see figures 5-5).

Figure 5-5 Restaurants along a street

Although shopping is one of the popular walking purposes, its destinations are spread across markets, supermarkets (buying groceries, etc.), shops (buying clothes, etc.) and restaurants and coffee shops (buying takeaway foods and drinks). Destinations, and origin of walking trips to change travel mode can either be bus stops, train stations or parking lots where people park their vehicles. In terms of recreational places, the most common outdoor destination are parks, flower gardens, squares, and lakes while common indoor destinations include gyms, sports halls, swimming pools, game or internet centres, karaoke, etc. Being only the least popular destination, spiritual places are special recreation destinations related to the religious culture of local people. There are a diverse and dense system of spiritual places including pagoda, temple, shrines, churches, and communal houses (Thi Nhu, 2017)

5.3.3.4 Accompanied walking

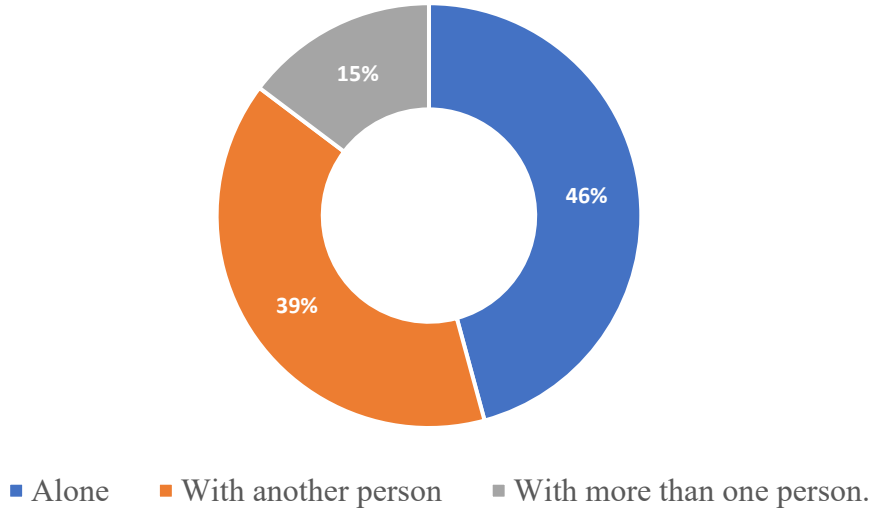

Figure 5-6 Percentage of walking trips that walkers are alone, with another person or in a group of more than two persons.

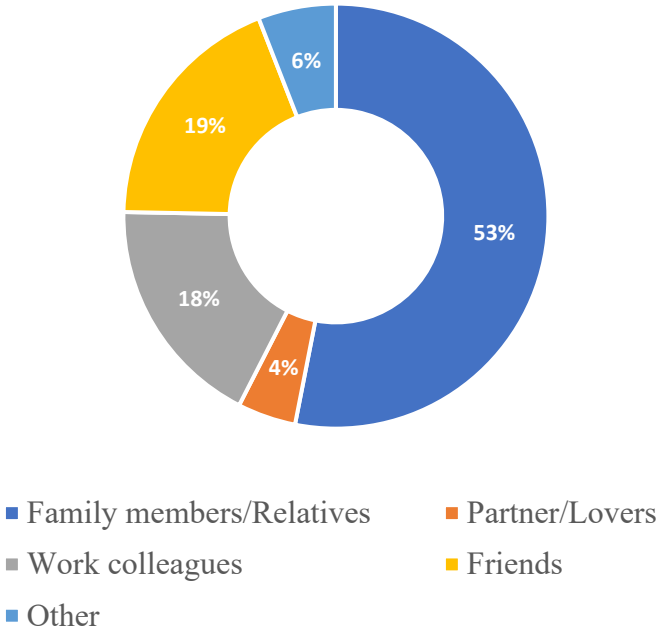

Figure 5-7. Type of accompaniers

Figure 5-6 shows that most participants walk alone or with another person. Only 15% of the walking trips are in a group of more than two people. Some common purposes for walking with other people are 'eat a meal', 'sport', 'accompany or transport someone' and 'recreation'. The accompaniers are mostly 'Family members or relatives' (53%),

followed by ‘Friends’ (19%) and ‘Colleagues at work’ (18%) (see Figure 5-7). ‘Family members’ and ‘Neighbours’ as accompaniers suggest the walking trips happened near home locations, while ‘Colleagues at work’ suggests the walking trips happened near work locations often in form of walking out for lunch or coffee.

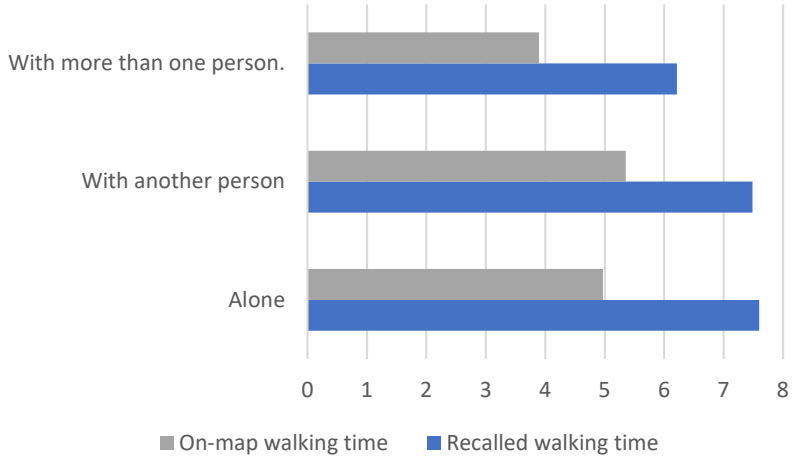

Figure 5-8 Walking time of accompanied trips

Hanoi people are likely to spend more time on a walking trip (7.6 minutes) when they walk alone than when they walk with another person (7.4 minutes) or in groups (6.2 minutes) (see Figure 5-8). This is a surprising result since walking in a group often gives more opportunities to talk to each other that often slows down the walks. However, the walking duration depends largely on the purpose and destination of the trips rather than the number of accompaniers. For example, in the case of commuting trips (e.g. walking children to/from school, walking to work or school) where fixed and tight schedules (e.g. school/work start time) are often required, shorter durations of walking are preferred even though there are accompaniers. Also, people can be more comfortable doing their things if they walk alone, for example, stopping to watch an event on the street without worrying the accompaniers are waiting.

5.3.3.5 Walking route selection

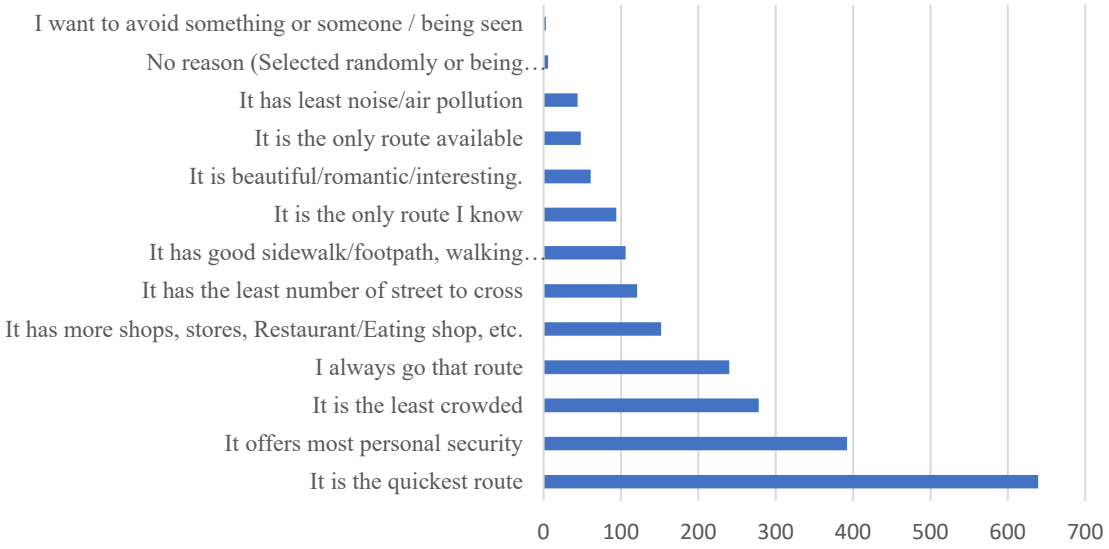

Figure 5-9 Personal reasons for choosing walking routes

The majority of walking routes (639 trips) have been chosen because they were the quickest ones leading to the desired destinations (see Figure 5-9). This result is expected since transportation trips, which are dominant in this research, are often influenced largely by time constraints. Streets density and intersection density would play an important role in creating shorter routes. 'Personal security/safety' and 'less crowded street' are the second and third important factors for people in choosing the walking route. Research by Tran et al. (2015) in Hanoi found that fear of crime was positively associated with motorcycle mode, suggesting that residents may think that walking is unsafe and switch to motorcycles. Most of the streets in Hanoi are overcrowded, especially during rush-hour, discouraging people from walking. In the study by Sanders (2013), Hanoi people found low-traffic volume streets to be more liveable to them. Participants preferred the route that 'has the least number of streets to cross', 'good sidewalk', and 'more shops and stores along'. The route that is beautiful or romantic is also attractive to the participants. Sometimes, they chose the route base on their habit or memory (they always choose some specific routes or only routes they know). Only a minor number of people considered noise or air pollution when choosing the walking route. Almost no one took a walking route just to avoid something or someone or for no reason at all (they just chose randomly or followed/are guided by others).

5.3.3.6 Recurrence and frequency

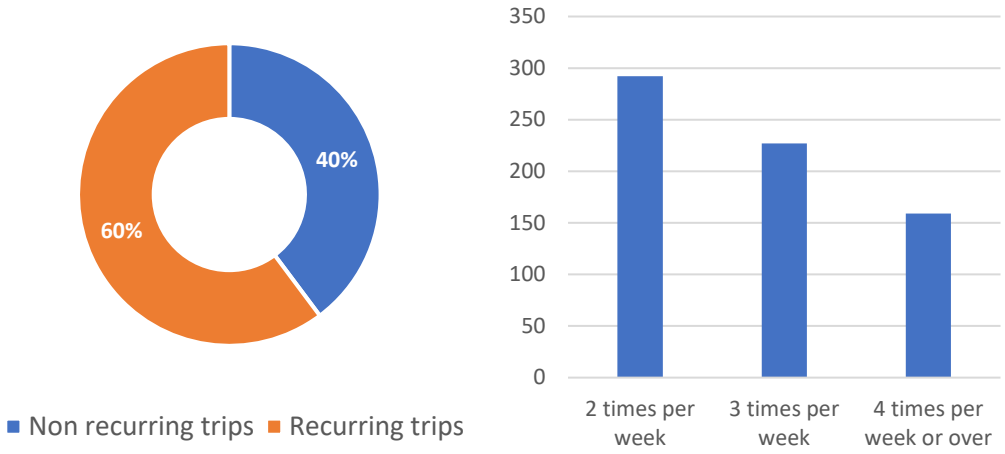

Figure 5-10 Recurrence and frequency of walking trips

60 per cent of the reported walking trips are recurring trips (see Figure 5-10). Participants mostly walked some specific routes that were repeated two times or three times a week. Fewer trips repeat four times or more a week (see Figure 5-10). The main purposes for recurring trips (excluding home-based trips) were 'sports', 'eating a meal', 'work commute' and 'shopping' (see Figure 5-11). It is understandable because they are common recurring activities and people tend to exercise in the same places (gym or park) every day, eat at their favourite restaurants or shop at their local markets.

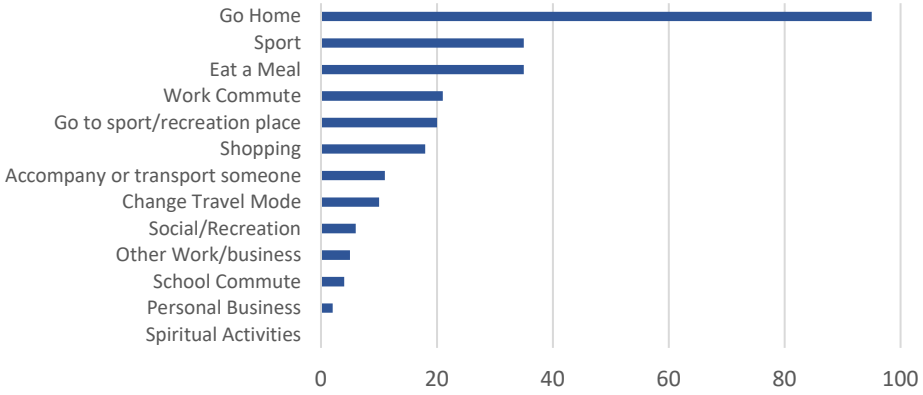

Figure 5-11 Common purposes for recurring trips.

5.3.4 Perceived barriers and facilitators.

Figure 5-12 shows the perceived barriers chosen by participants. 19 per cent of people reported that they don't walk because 'they 'don't have time (or are too busy)', which often leads to the use of motorised vehicles with the advantage of speed. More than 15 per cent think they're just too lazy to walk. Other personal reasons to discourage people from walking include' having to carry things', 'being in a bad mood', 'being too tired', 'don't have people to walk with' or 'having to travel with small children'. Health conditions or lack of fitness are also barriers to some people. Only a few people reported that they just don't like walking and feel that walking is boring. Research from Bupa (2013) also reported that people in the UK cited similar barriers such as 'don't have enough time', 'too tired', 'lack of health/fitness' or 'don't have people to walk with'.

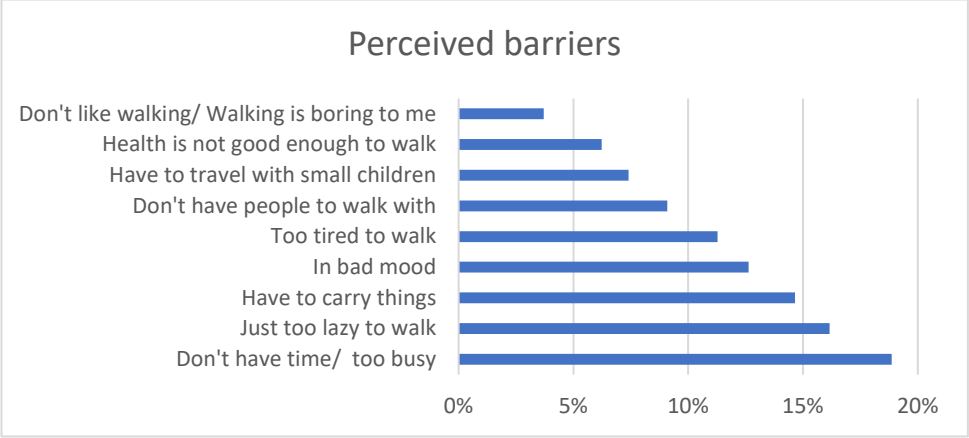

Figure 5-12 Perceived barriers for walking

Figure 5-13 shows the perceived facilitators chosen by participants. Many participants agreed that the belief that 'walking is good for health' is still the best motivation for them to walk more. 'Having free time', 'having people to walk with', and 'being in a good mood' were the other popular reasons to walk, which seem to relate to walking for recreation. Some people acknowledged the fact that walking helps to protect the environment. Others chose walking over other transport modes of transport for economic reasons because walking is free for everyone, and they don't afford private vehicles.

Figure 5-13 Perceived facilitators for walking

5.3.5 Associations of walking by regression models

5.3.5.1 The logistic regression models.

Table 5-6 Logistic regression model 1: the likelihood of walking by demographic factors

Parameters	Logistic regression model 1 DV: Walking in general (N=215, model Nagelkerke R^2 = 0.816)						
	B	S.E.	Wald	Sig.	Exp(B)	95% C.I	
						Lb	Ub
Age	.163	.112	2.099	.147	1.177	.944	1.466
Gender							
Male (reference)							
Female	-2.532	1.289	3.856	.050	.080	.006	.995
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	1.991	2.797	.507	.477	7.321	.030	1760.251
Single (never married)	2.476	2.578	.922	.337	11.889	.076	1861.257
Education level							
College/High school or lower (reference)							
University or higher	-2.727	2.654	1.056	.304	.065	.000	11.879
Occupation status							
Employed (reference)							
Retired/Unemployed	-3.002	3.455	.755	.385	.050	.000	43.333
Self-employed	-3.099	2.591	1.430	.232	.045	.000	7.239
Student	-.886	3.689	.058	.810	.412	.000	568.885
BMI	-2.182	.586	13.860	**<.001**	.113	.036	.356
Household Members	1.334	.721	3.423	.064	3.795	.924	15.587
Motorised vehicles ownership							
Have motorised vehicles (reference)							
No motorised vehicles	.312	2.027	.024	.878	1.366	.026	72.628
Children in household							
Have children (reference)							
No children	.033	2.310	.000	.988	1.034	.011	95.607
Urban typologies							
Constant	48.809	14.335	11.593	<.001	1.5E+21		

Note: bold texts indicate p-value < 0.05

In model 1, logistic regression was used to test the contributions of demographic characteristics in predicting the likelihood that participants had engaged in walking. The overall model was found to be statistically significant with $\chi2(12, N=215) = 101.56$, $p < .001$. The model explained 81.6% (Nagelkerke R^2) of the variance in walking and correctly classified 97.7% of cases. BMI was found to be statistically significant in predicting one's odds of walking ($\chi2$ (1) = 13.8, $p < .001$). In particular, the odds of one

engaging in walking will be decreased by 88.7% for every additional increase in BMI (OR = 0.113, 95% CI = 0.036 – 0.356).

Table 5-7 Logistic regression model 1: the likelihood of walking by urban typologies adjusted for demographic factors

Parameters	Logistic regression model 2 DV: Walking inside neighbourhood (N=215, model Nagelkerke R^2 = 0.665)						
	B	S.E.	Wald	Sig.	Exp(B)	95% C.I	
						Lb	Ub
Age	-.067	.057	1.373	.241	.935	.836	1.046
Gender							
Male (reference)							
Female	.519	.720	.520	.471	1.680	.410	6.884
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	.940	1.594	.348	.555	2.560	.113	58.217
Single (never married)	-.060	1.301	.002	.963	.942	.073	12.067
Education level							
College/High school or lower (reference)							
University or higher	.406	1.029	.155	.693	1.500	.200	11.264
Occupation status							
Employed (reference)							
Retired/Unemployed	4.459	1.885	5.597	**.018**	86.365	2.149	3471.525
Self-employed	1.966	1.414	1.933	.164	7.140	.447	114.108
Student	.215	1.471	.021	.884	1.239	.069	22.167
BMI	-.884	.185	22.863	**<.001**	.413	.288	.594
Household Members	.326	.415	.619	.432	1.385	.615	3.122
Motorised vehicles ownership							
Have motorised vehicles (reference)							
No motorised vehicles	.563	1.481	.145	.704	1.757	.096	32.004
Children in household							
Have children (reference)							
No children	-.839	.856	.961	.327	.432	.081	2.312
Urban typologies							
Ancient Quarter	1.485	1.049	2.002	.157	4.413	.564	34.508
French Quarter	1.680	.851	3.898	**.048**	5.366	1.012	28.444
Collective Housing Quarter	3.804	1.467	6.721	**.010**	44.874	2.530	795.968
Urbanised Village Area	2.977	1.140	6.820	**.009**	19.624	2.101	183.245
Constant	21.840	5.329	16.795		3.0E+9		

Note: bold texts indicate p-value < 0.05

In model 2, to predict the likelihood of walking inside the neighbourhood, the dependent variable was changed to walking inside the neighbourhood and urban typologies were added as independent variables. The overall model was found to be

statistically significant $\chi 2(16, N=215) = 102.256$, $p < .001$. The model explained 66.5% (Nagelkerke R^2) of the variance in walking and correctly classified 92.6% of cases. BMI, Retired and Unemployed and three Urban Typologies were found to be statistically significant in predicting one's odds of walking. Each additional increase in BMI is associated with a 58.7% decrease in the odds of one engaging in walking (OR = 0.113, 95% CI = 0.036 – 0.356). The odds of walking are 86 times greater for Retired or Unemployed people as opposed to Employed ones (OR = 86.3, 95% CI = 2.149-3471.525). In terms of urban typologies, the odds of walking for people living in the New Urban Area are 5.4 times, 44.8 times and 19.6 times less than the odds of walking for people living in the French Quarter (OR = 5.4, 95% CI = 1.012-28.444), Collective Housing Quarter (OR = 44.8, 95% CI = 2.530-795.968) and Urbanised Village Areas (OR = 19.7, 95% CI = 2.101-183.245) respectively.

5.3.5.2 Generalized linear models

In model 3 (see Table 5-8), age, marital status of divorced/widowed/separated and single, education level of university and higher, and student occupation status were found to be positively associated with the total time of walking per day. Each one year increase in age predicts a multiplicative increase of 1.019 (or 1.9% increase) in the mean amount of walking time. A person who is divorced/widowed/separated or single (never married) is likely to walk 1.563 times or 1.256 times, respectively, more than someone married. Students are expected to have a total walking time that is 1.338 times higher than employed ones. On the other hand, BMI is negatively associated with total walking times. One increase in BMI leads to a multiplicative decrease of 1.21 in the number of walking times.

Table 5-8 Association between total walking time and demographic factors

Parameters	GLM model 3 DV: Total walking time (N=195)						
	B	SE	95% CI		Wald	Exp(B)	Sig.
			Lb	Ub			
(Intercept)	6.007	.4645	5.097	6.917	167.243	406.23	.000
Age	.019	.0048	.010	.029	16.342	1.019	**<.001**
Gender							
Male (reference)							
Female	.124	.0680	-.009	.257	3.318	1.132	.069
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	.447	.1483	.156	.737	9.072	1.563	**.003**
Single (never married)	.228	.1144	.004	.452	3.970	1.256	**.046**
Education level							
College/High school or lower (reference)							
University or higher	.175	.0858	.007	.343	4.177	1.192	**.041**
Occupation status							
Employed (reference)							
Retired/Unemployed	.010	.1377	-.260	.280	.005	1.010	.943
Self-employed	.129	.1095	-.085	.344	1.398	1.138	.237
Student	.289	.1287	.037	.541	5.038	1.335	**.025**
BMI	-.168	.0180	-.204	-.133	87.096	.845	**.000**
Household Members	.002	.0360	-.069	.073	.003	1.002	.959
Motorised vehicles							
Have motorised vehicles (reference)							
No motorised vehicles	-.176	.1024	-.377	.025	2.957	.838	.085
Children in household							
Have children (reference)							
No children	-.147	.0775	-.299	.005	3.577	.864	.059

Note: bold texts indicate p-value < 0.05

In model 4 (see Table 5-9), the dependent variable was changed to walking time inside the neighbourhood and urban typologies were added as independent variables after being dummy coded. Age, and marital status of divorced/widowed/separated were found to be positively associated while having no motorised vehicles and BMI was negatively associated with the amount of walking inside the neighbourhood. In terms of urban typologies, with New Urban Areas as a reference, the French Quarter and Collective Housing Quarters are negatively associated with the walking time inside the neighbourhood. People in French Quarter and Collective Housing are expected to have walking time that 0.732 and 0.718 times, respectively, less than people in New Urban Areas.

Table 5-9 Association between total walking time and urban typologies adjusted for demographic factors

Parameters	GLM model 4 DV: Walking time inside the neighbourhood (N=183)						
	B	SE	95% CI		Wald	Exp(B)	Sig.
			Lb	Ub			
(Intercept)	5.947	.6157	4.740	7.154	93.303	382.66	.000
Age	.019	.0061	.007	.031	10.056	1.019	**.002**
Gender							
Male (reference)							
Female	.146	.0854	-.022	.313	2.909	1.157	.088
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	.412	.1818	.056	.769	5.139	1.510	**.023**
Single (never married)	.232	.1408	-.044	.508	2.723	1.262	.099
Education level							
College/High school or lower (reference)							
University or higher	.091	.1101	-.124	.307	.689	1.096	.406
Occupation status							
Employed (reference)							
Retired/Unemployed	.071	.1809	-.284	.426	.154	1.074	.695
Self-employed	.227	.1351	-.037	.492	2.834	1.255	.092
Student	.118	.1634	-.202	.439	.524	1.126	.469
BMI	-.158	.0241	-.205	-.110	42.835	.854	**<.001**
Household Members	.002	.0495	-.095	.099	.002	1.002	.968
Motorised vehicles							
Have motorised vehicles (reference)							
No motorised vehicles	-.260	.1299	-.515	-.006	4.011	.771	**.045**
Children in household							
Have children (reference)							
No children	-.139	.0969	-.329	.051	2.046	.871	.153
Urban typologies							
Ancient Quarter	-.156	.1530	-.456	.143	1.045	.855	.307
French Quarter	-.312	.1417	-.590	-.035	4.861	.732	**.027**
Collective Housing Quarter	-.332	.1452	-.617	-.047	5.224	.718	**.022**
Urbanised Village Area	-.247	.1409	-.524	.029	3.082	.781	.079

Note: bold texts indicate p-value < 0.05

In model 5 (see Table 5-10), age, single as marital status, BMI, self-employed and student as occupation status were found to be positively associated with walking time per trip. Each one-year increase in age predicts a multiplicative increase of 1.017 (or 1.7% increase) in the mean of walking time per trip. People who are single (never married) have a mean walking time per trip that is 1.4 times longer than someone married. Students

and self-employed are expected to the mean walking time per trip 1.3 times longer than employed ones. One increase in BMI leads to a multiplicative increase of 1.04 in the amount of walking time. On the other hand, people that have no children are likely to have a walking time per trip 0.851 times less than people with children.

Table 5-10 Association between walking time per trip and demographic factors

Parameters	GLM model 5 DV: Walking time per trip (N=195)						
	B	SE	95% CI		Wald	Exp(B)	Sig.
(Intercept)	.421	.4915	-.542	1.384	.734	1.524	.392
Age	.017	.0052	.006	.027	10.226	1.017	**.001**
Gender							
Male (reference)							
Female	.117	.0718	-.024	.258	2.661	1.124	.103
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	.289	.1563	-.017	.596	3.431	1.336	.064
Single (never married)	.358	.1205	.122	.594	8.836	1.431	**.003**
Education level							
College/High school or lower (reference)							
University or higher	.069	.0898	-.107	.245	.245	1.071	.445
Occupation status							
Employed (reference)							
Retired/Unemployed	.065	.1477	-.224	.355	.195	1.067	.658
Self-employed	.291	.1191	.057	.524	5.962	1.338	**.015**
Student	.310	.1366	.042	.577	5.131	1.363	**.024**
BMI	.041	.0190	.004	.079	4.709	1.042	**.030**
Household Members	-.047	.0385	-.123	.028	1.518	.954	.218
Motorised vehicles							
Have motorised vehicles (reference)							
No motorised vehicles	-.120	.1103	-.336	.097	1.175	.887	.278
Children in household							
Have children (reference)							
No children	-.162	.0816	-.321	-.002	3.928	.851	**.047**

Note: bold texts indicate p-value < 0.05

In model 6 (see Table 5-11), the dependent variable was changed to walking time per trip inside the neighbourhood and urban typologies were added as independent variables after being dummy coded. Age, single as marital status, and self-employed as occupation status were still positively associated with walking time per trip inside the neighbourhood. In terms of urban typologies, with New Urban Areas as the reference variable, both four other urban typologies are negatively associated walking time per trip,

suggesting people living in those urban typologies have an average walking time per trip shorter than ones in New Urban Areas. People in the Ancient Quarter, French Quarter, Collective Housing Quarter and Urbanised Villages Areas are expected to have walking time per trip that 5.9 times, 12.7 times, 19.7 times and 12.5 times, respectively, shorter than the walking time per trip of residents in New Urban Areas.

Table 5-11 Association between walking time per trip inside the neighbourhood and urban typologies adjusted for demographic factors

Parameters	GLM model 6 DV: Walking time per trip inside the neighbourhood (N=183)						
	B	SE	95% CI		Wald	Exp(B)	Sig.
(Intercept)	.948	.5276	-.086	1.982	3.230	2.581	.072
Age	.017	.0055	.006	.028	9.597	1.017	**.002**
Gender							
Male (reference)							
Female	.143	.0746	-.003	.289	3.664	1.153	.056
Marital status							
Married (reference)							
Divorced/Widowed/ Separated	.291	.1586	-.020	.602	3.363	1.337	.067
Single (never married)	.355	.1233	.113	.596	8.274	1.426	**.004**
Education level							
College/High school or lower (reference)							
University or higher	.045	.0943	-.140	.230	.225	1.046	.635
Occupation status							
Employed (reference)							
Retired/Unemployed	-.024	.1620	-.341	.294	.021	.977	.884
Self-employed	.244	.1198	.009	.479	4.144	1.276	**.042**
Student	.235	.1406	-.040	.511	2.802	1.265	.094
BMI	.029	.0207	-.012	.069	1.907	1.029	.167
Household Members	-.009	.0424	-.092	.074	.043	.991	.836
Motorised vehicles							
Have motorised vehicles (reference)							
No motorised vehicles	-.191	.1132	-.413	.031	2.845	.826	.092
Children in household							
Have children (reference)							
No children	-.138	.0839	-.302	.027	2.702	.871	.100
Urban typologies							
Ancient Quarter	-.324	.1334	-.585	-.062	5.890	.723	**.015**
French Quarter	-.448	.1255	-.694	-.202	12.752	.639	**<.001**
Collective Housing Quarter	-.557	.1254	-.803	-.312	19.766	.573	**<.001**
Urbanised Village Area	-.427	.1207	-.664	-.190	12.507	.653	**<.001**

Note: bold texts indicate p-value < 0.05

5.3.5.3 Discussion of results from regression models.

Findings from the six models show that demographic characteristics and urban typologies have significantly influenced walking behaviours. People with lower BMI have a higher chance of engaging in walking both inside and outside neighbourhoods and have a higher amount of walking times as well, only that their average trip length is shorter. In other words, their frequent walking may be the factor contributing to their healthy BMI level. However, this result seems to contradict other studies from Vietnam which showed that higher BMI is related to higher levels of physical activity (Nguyen, Nguyen, Ngo, Nguyen, & Phan, 2020; Vuong et al., 2018). The difference can be explained by the fact that walking is only a part of the physical activities and overweighted people may pick other exercises or sports rather than walking to lose weight, especially those who have such conditions that don't suit walking such as living in an area with extreme air pollution or with crowded traffic but no sidewalk. Extended studies to examine the association between the BMI status of people and their walking behaviour should be warranted. The age of participants was significantly associated with the amount of walking and the average duration of a trip both inside their neighbourhood and other places, suggesting that older people walk more and have longer walking time per trip, which confirmed the finding from the descriptive analysis. Students as occupation status and single as marital status have a significantly higher amount of walking and longer walking trip than employed and married people. However, there is a high possibility of collinearity between students and single people, therefore further research is recommended.

In terms of walking inside the neighbourhood, the most influential factors are urban typologies, or the areas people live. People living in New Urban Area have significant low odds of engaging in walking compared to those in the French Quarter and Collective Housing Quarters. They may not engage in walking at all or only walk outside their neighbourhood such as at the workplace or school. However, people in New Urban Area, who do walk, have a considerably higher amount of walking time than those in the French Quarter and Collective Housing Quarters. This high amount of walking time is contributed by their exceedingly long average walking time per trip which is 6 to 20 times longer than people in all other urban typologies, as per the result from model 6. These results can be explained by the urban form characteristics of those urban typologies. The urban form in New Urban Area is characterised by low built-up density and low mixed land use, which may make residents there have to walk longer to reach their utilitarian

destinations. On the other hand, in comparison to other highly dense urban typologies, the New Urban Area has more public spaces such as parks, lakes and squares which can encourage more amount of walking for recreation.

5.4 Summary.

Chapter 5 describes and discusses the results of Sub-study 1: the prevalence and characteristics of walking. The Chapter discussed the modal share of walking, the common purposes, duration and distance, origin and destination of walking trips, prevalence of accompanied, recurring and repeated walking trips, as well as reasons for choosing the walking routes. The perceived barriers and facilitators of walking were also summarised. Finally, the chapter showed the associations between urban typologies and the likelihood of walking, the walking time as well as the walking time per trip.

5.5 References

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CHAPTER 6 PERCEIVED URBAN DESIGN AND WALKING

6.1 Chapter introduction

As highlighted in Chapter 2, research on physical activity including walking is a highly researched field in medicine and public health with a focus on the health benefits and the relationship between individual characteristics and social factors. In recent decades, walking has become increasingly recognised for its co-benefits and contribution to not only individual health but also public health, the environment, and the economy. Therefore, research interests in walking have arisen across disciplines including transportation, urban design and planning, with the research in these later disciplines focused on the links between the built environment and physical activity. One of the challenges in this field however, is how to measure the features of the built environment associated with walking such that the outcomes are valid, reliable, and feasible way (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Spittaels et al., 2010). As mentioned in Chapter 2, studies in this field of research have typically used two types of measures: objective measures and perceived measures. Despite their usefulness and popularity, the objective measures such as those using D variables (e.g., density, diversity, design) are argued to be insufficient in representing the urban environment in terms of physical activity friendliness (Sallis et al., 2011). The gross characteristics of urban physical attributes collected from objective measures may not affect the experience people have whilst using the street (Ewing, Hajrasouliha, Neckerman, Purciel-Hill, & Greene, 2015). Another problem is that obtaining objective spatial data can be challenging and costly (Brownson et al., 2009) because they may be insufficient, inconsistent, not available, or administratively burdensome to use, especially in low- and middle-income countries (Porter, Kirtland, Williams, Neet, & Ainsworth, 2004; Salvo, Reis, Sarmiento, & Pratt, 2014). Exploring residents' perceptions of the built environment through perceived measures is important as it compliments data from objective measures and contributes to a better understanding of walking behaviour (Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005; McCormack, Cerin, Leslie, Du Toit, & Owen, 2007; Parra et al., 2010). Importantly, there are numerous established tools that measure a residents perception of the walking environment such as the Perceived Walking Environment Tool (Humpel, Marshall, Leslie, Bauman, & Owen, 2004), the Neighbourhood Walking Survey (Li, Fisher, & Brownson, 2005), the Perceptions of Environmental Support Questionnaire (Kirtland et al., 2003). Among the tools, the

Neighbourhood Environment Walkability Scale (NEWS) (Saelens, Sallis, Black, & Chen, 2003) and its abbreviated version (NEWS-A) have been used most extensively (Cerin, Leslie, Owen, & Bauman, 2008; Cerin, Macfarlane, Ko, & Chan, 2007; Oyeyemi et al., 2016). However, these tools have been developed in US and research using them comes from high-income countries such as the USA, Australia, and European countries, where cities are less dense in both population and destination compared to many low-income cities across the Asian continent (Cerin et al., 2007). Research in this field is still underrepresented in Asia where cities exhibit local walking-related characteristics (e.g., air pollution, crowdedness, diverse terrain, diverse destinations) that differ enormously to less dense locations (Cerin et al., 2007). Some studies have attempted to apply the tools like NEWS in the Asian context, but only from developed countries like Japan (Inoue et al., 2009), China (Cerin et al., 2007), and South Korea (Kim et al., 2016) where the urban design and urban and transport infrastructure are already well-developed. In most developing countries in Asia – like Vietnam, cities are only beginning to see rapid urban development (Chen, Chiu, & Lin, 2020). Such cities have high density with a vibrant mix of uses, but these dense forms and mixed-use usually come from historical fluctuations and unregulated development rather than official planning and where development is generally associated with underdeveloped urban infrastructure (Storch, Eckert, & Pfaffenbichler, 2008). Research to fully understand the impact of those characteristics on perceived urban design and walking is essential to develop suitable urban design and transport policies and strategies. Sub-study 2, described in the present Chapter, systematically adapted the NEWS-A tool to measure perceived urban design in Hanoi, a city in developing countries in Asia. The study also compared ratings of perceived urban design among five typical urban typologies across Hanoi to highlight the influence of urban typologies on perceived urban design. This chapter presents and discuss the obtained findings.

6.2 Methods

Methods for this study (Sub-study 2) were described in section 4.4 of Chapter 4.

The five urban design typologies are Ancient Quarter, French Quarter, Collective Housing Quarters, Urbanised Village Areas, and New Urban Areas. These urban design typologies are identified and described in section 3.4 of Chapter 3 and section 4.3.3 of Chapter 4.

Figure 5-1 illustrates the research framework and the main contents of Sub-study 2.

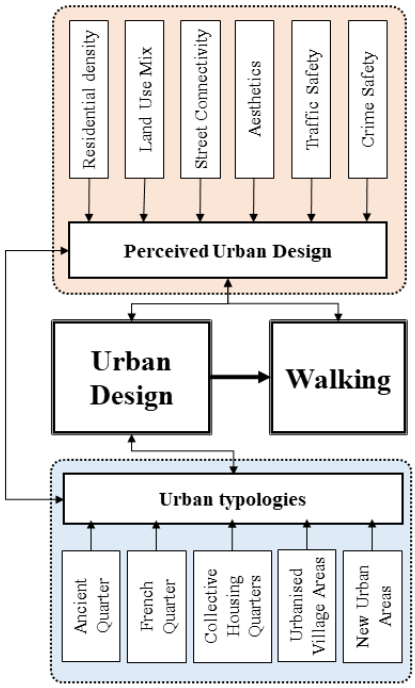

Figure 6-1 Research framework of Sub-study 2

6.3 Results

6.3.1 The test-retest reliability

The test-retest reliability scores of the adapted questionnaire are reported in Table 6-2 and Table 6-3. ICCs of the subscales ranged from 0.74 to 0.92, showing good to excellent reliability levels. ICC scores of the individual items of the adapted questionnaire ranged from 0.62 to 0.98 showing moderate to excellent reliability. The item with the lowest reliability score (ICC=0.62) was 'Unsafe to walk during the day' in the 'Crime Safety' subscale and the highest score related to the 'Residential Density' subscale (Detached single-family residences) with an ICC=0.98 score. Both 'Land use Mix-Diversity' and 'Residential Density' subscales scores were above 0.91 with items ranging from 0.66 to 0.98.

Table 6-1 Mean scores, standard deviation and test-retest reliability scores of the subscales and items in NEWS-A-V

Subscale/Item	Mean	SD	ICC
Residential Density	308.41	82.88	0.92
Detached single-family residences	2.13	1.25	0.98
Townhouses or row houses	**3.74**	0.83	0.91
Apartments with 1-3 stories	2.07	1.26	0.93
Apartments with 4-6 stories	2.07	1.26	0.88
Apartments with 7-12 stories	1.63	0.71	0.81
13+ story apartments	*1.43*	0.63	0.92
Land use Mix-Diversity	3.91	0.56	0.91
Convenience/small grocery store	4.55	0.65	0.83
Supermarket/big market	3.68	0.88	0.94
Hardware store	3.33	1.24	0.89
Small market/ vegetable market	4.10	0.72	0.82
Laundry/dry cleaners	3.86	1.07	0.85
Clothing store	4.25	0.89	0.73
Post office	3.52	1.10	0.87
Library	3.20	1.28	0.91
Elementary school	3.97	0.81	0.69
Other schools	3.90	0.87	0.78
Book store	3.90	1.05	0.78
Fast food restaurant	4.36	0.74	0.87
Coffee place	**4.65**	0.66	0.88
Bank	4.26	0.81	0.82
Non-fast-food restaurant	4.44	0.75	0.90
Games/internet café	3.41	1.33	0.86
Pharmacy	4.39	0.73	0.87
Your job or school	*2.92*	1.62	0.95
Bus stop	4.44	0.85	0.78
Park	3.76	1.00	0.91
Sports centre/Football field/swimming pool	3.33	1.07	0.83
Gym or fitness facility	3.44	1.06	0.94
Pagoda, Church	4.00	0.85	0.70
Hair salon, beauty salon	4.29	0.70	0.66
Land use Mix-Access	2.72	0.37	0.74
Stores are within walking distance	2.90	0.78	0.80
Many places within walking distance	2.59	0.76	0.85
Easy to walk to transit stop	**3.07**	0.67	0.87
Parking is difficult in local shopping areas (in)	2.55	0.92	0.86
Major barriers to walking (in)	*2.51*	0.77	0.84
Street connectivity	2.99	0.61	0.89
Short distance between intersections (<100 metres)	*2.87*	0.83	0.89
Many alternate routes	**3.21**	0.63	0.88
Not many dead-end routes	2.88	0.69	0.85
Walking facilities	2.81	0.47	0.89
Sidewalks on most streets	3.00	0.77	0.86
Painted line separates walking area from parking area	2.66	0.82	0.94
Sidewalks are well maintained	2.86	0.83	0.91
Streets are well lit at night	**3.19**	0.48	0.73
Walkers can be seen by people from their homes	2.72	0.77	0.85
Crosswalks and pedestrian signals are available	3.02	0.73	0.77
Sidewalks is encroached or obstructed (in)	*2.20*	0.79	0.71
Aesthetics	2.51	0.37	0.88
Trees along the streets	**2.85**	0.84	0.88
Interesting things to look at	2.55	0.70	0.81
Attractive natural sights	*2.16*	0.83	0.90
Attractive buildings	2.23	0.73	0.71

Subscale/Item	Mean	SD	ICC
Traffic safety	2.63	0.33	0.83
Heavy traffic along nearby streets (in)	*2.16*	0.77	0.86
Slow speed of traffic along nearby streets (<50 kph)	2.82	0.71	0.86
Drivers exceed speed limits (in)	**2.91**	0.52	0.80
Crime safety	3.09	0.29	0.85
High crime rate makes unsafe to walk (in)	*3.11*	0.61	0.79
Unsafe to walk in during the day (in)	**3.37**	0.48	0.62
Unsafe to walk in during the night (in)	*3.11*	0.55	0.82

Note: boldface font indicates that the maximum values, italic font indicates minimum values.
(re) indicates items that were reversely computed.

Table 6-2 reports the ICC scores of eight subscales across different country versions of NEWS and NEWS-A. NEWS-A China had the highest ICC scores of Land use mix (0.99)

Table 6-2 Test-retest reliability scores of the original and adapted NEWS and NEWS-A

Subscales	NEWS USA Original (Saelens et al., 2003)	NEWS Australia (Evenson & McGinn, 2005)	NEWS Nigeria (Oyeyemi et al., 2013)	NEWS-A Japan (Inoue et al., 2009)	NEWS-A South Korea (Kim et al., 2016)	NEW-A China (Cerin et al., 2007)	NEWS-A Vietnam
Residential Density	0.63	0.78	0.66	0.95	0.82	0.93	0.92
Land use mix	0.78	0.88	0.87	0.96	0.88	0.95	0.91
Access to services	0.79	0.80	0.76	0.90	0.81	0.99	0.74
Street Connectivity	0.63	0.74	0.72	0.83	0.75	0.97	0.89
Walking facilities	0.58	0.76	0.59	0.82	0.83	0.57	0.89
Aesthetics	0.79	0.86	0.91	0.84	0.85	0.89	0.88
Traffic Safety	0.77	0.62	0.65	0.81	0.77	0.74	0.83
Crime Safety	0.80	0.63	0.66	0.76	0.83	0.92	0.85

6.3.1 Perceived urban design

As can be seen from Table 6-2, participants considered townhouses or row houses as the most popular residential typology (3.74 out of 5) while the least popular were apartments with over 13 stories (1.43 out of 5)

6.3.2 Associations between perceived urban design and urban typologies

Table 6-3 reported the perceived urban design by demographics and urban typologies. People in the youngest age group (18-24) had the highest mean score of

Residential Density while the oldest group (60+) perceived the highest mean score of Street Connectivity. Males and females shared similar perceptions of urban design except for Traffic Safety where males rated the traffic of Hanoi higher than females. Among five urban typologies, Ancient Quarter had the highest score in Land Used Mix, Street Connectivity, and Traffic Safety. New Urban Areas had the highest score in Residential Density and Walking Facilities.

Table 6-3 Perceived urban design by age, gender, education level and urban typology.

	Residential Density		Land Use Mix		Access to services		Street Connectivity		Walking Facilities		Aesthetics		Traffic Safety		Crime Safety	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age																
18-24	**314.83**	90.69	3.89	0.52	2.72	0.36	*2.86*	0.55	2.80	0.40	2.50	0.34	2.57	0.28	*3.07*	0.22
25-44	309.40	78.70	**3.97**	0.52	*2.71*	0.38	2.98	0.61	2.79	0.45	**2.55**	0.32	2.67	0.27	*3.07*	0.27
45-59	*296.35*	88.80	*3.75*	0.67	**2.76**	0.42	3.13	0.58	**2.93**	0.52	2.44	0.46	**2.68**	0.38	**3.18**	0.32
60+	303.72	77.78	3.90	0.67	2.73	0.32	**3.17**	0.75	*2.71*	0.69	*2.35*	0.50	*2.52*	0.59	**3.18**	0.44
Gender																
Male	*307.25*	82.80	**3.92**	0.51	**2.75**	0.34	*2.96*	0.62	**2.81**	0.45	**2.53**	0.36	**2.66**	0.29	*3.04*	0.23
Female	**309.60**	83.35	*3.90*	0.60	*2.69*	0.40	**3.02**	0.60	*2.80*	0.50	*2.48*	0.37	*2.60*	0.36	**3.14**	0.33
Education Level																
High school/college or lower	**310.24**	80.82	**3.99**	0.59	**2.76**	0.38	**3.08**	0.62	*2.73*	0.48	*2.44*	0.37	*2.56*	0.36	*3.09*	0.31
University or higher	*307.12*	84.61	*3.86*	0.53	*2.70*	0.37	*2.92*	0.59	**2.86**	0.46	**2.55**	0.36	**2.68**	0.30	**3.10**	0.27
Urban typology																
Ancient Quarter	*254.60*	67.03	4.06	0.34	**2.93**	0.24	**3.40**	0.52	2.77	0.32	2.71	0.26	**2.80**	0.24	3.13	0.25
Collective Housing Quarter	280.00	57.78	3.72	0.35	2.81	0.20	3.05	0.55	3.11	0.34	**2.79**	0.20	2.70	0.35	**3.20**	0.27
French Quarter	275.21	84.99	**4.44**	0.49	2.83	0.24	3.12	0.66	*2.43*	0.51	2.38	0.35	2.64	0.17	3.05	0.24
Urbanised Village Area	307.21	78.73	3.90	0.62	2.82	0.28	*2.46*	0.32	2.51	0.30	*2.22*	0.38	*2.51*	0.43	*3.02*	0.33
New Urban Area	**325.02**	71.46	*3.45*	0.40	*2.22*	0.37	2.91	0.54	**3.21**	0.28	2.44	0.30	*2.51*	0.31	3.07	0.30

Note: boldface font indicates that the maximum values, italic font indicates minimum values.

Figure 6-2 compared the perceived urban design across five urban typologies. French Quarter has a higher score for Crime safety than Ancient Quarter and Urbanised Village Areas.

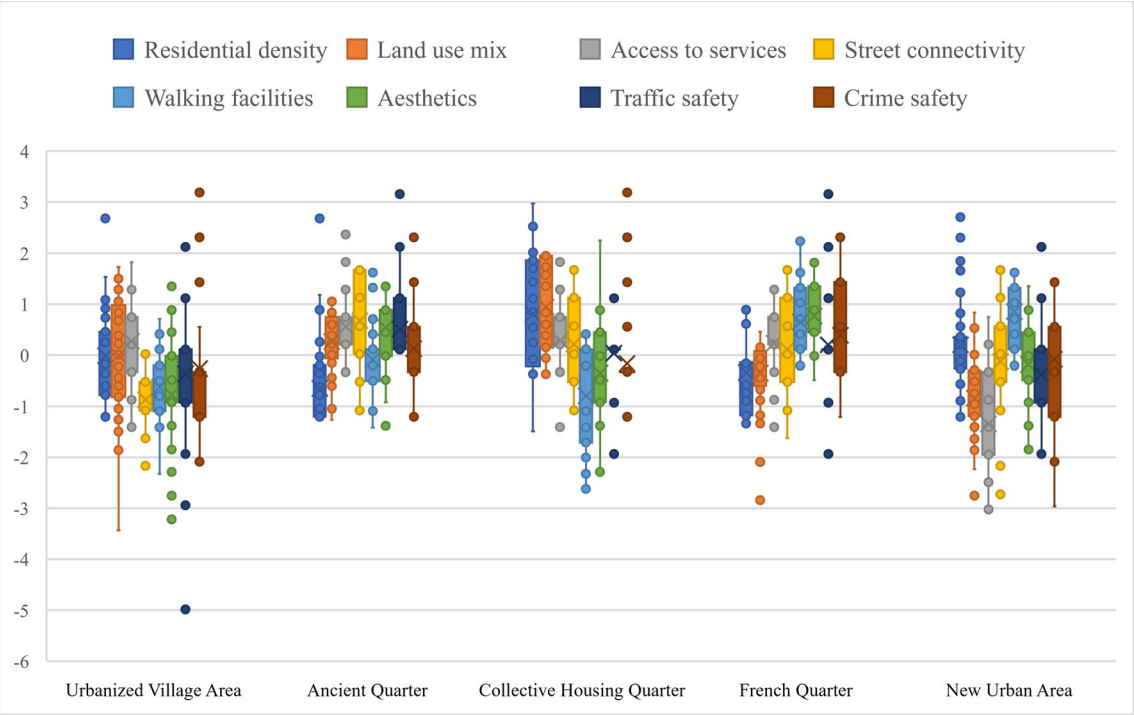

Figure 6-2 Z-score of perceived urban design subscales for five urban typologies

Table 6-4 shows the associations between perceived urban design and urban typologies. In terms of perceived Residential Density, the Ancient Quarter and French Quarter had significantly lower scores while Collective Housing Quarter had a significantly higher score compared with the Urban New Areas (the reference urban typology). Urban New Areas had a significant lower perceived Lan Use Mix than all other urban typologies

Table 6-4 Associations between perceived urban design and urban typologies

Urban typologies	Residential Density	Land Use mix	Access to Services	Street Connectivity	Walking facilities	Aesthetics	Traffic Safety	Crime Safety	Total Score
Ancient Quarter	**-70.419**	**.616**	**.707**	**.488**	**-.444**	**.266**	**.289**	.058	**-68.439**
	<.001	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	.337	**<.001**
French Quarter	**-45.023**	**.271**	**.586**	.148	-.097	**.349**	**.188**	.134	**-43.445**
	.004	**.006**	**<.001**	.197	.210	**<.001**	**.006**	.028	**.006**
Collective Housing Quarter	**50.186**	**.993**	**.605**	.209	**-.778**	-.060	**.134**	-.023	**51.265**
	.002	**<.001**	**<.001**	.068	**<.001**	.357	**.047**	.700	**.001**
Urbanised Village Area	-17.814	**.458**	**.600**	**-.451**	**-.698**	**-.213**	.002	-.052	-18.168
	.257	**<.001**	**<.001**	**<.001**	**<.001**	**.001**	.978	.387	.249

Note: New Urban Areas is the reference urban typology, boldface font indicates that the coefficient is statistically significant

6.3.3 Associations between perceived urban design and walking

Table 6-5 shows the result from the Zero-Inflated Poisson regression on the association between perceived urban design and walking. The logit model, presented in the lower part of the table, shows that Land Use Mix is negatively associated with the odds of not engaging in walking, which means that people who perceived a higher level of Land Use Mix are likely to be a walker. With every additional unit in the score of perceived Land Use Mix, the odds to be a non-walker decrease by a factor of 0.003. Conversely, Street Connectivity is positively associated with the odds of being a non-walker. People who perceived higher street connectivity levels are less likely to walk.

The upper part of Table 6-5 (the Poisson regression model) shows that 'Land use access' or 'Access to services' was positively associated with the number of walking trips. An increase in the Access to Services perception would lead to an increase by a factor of 1.565 in the number of walking trips. In contrast, perceived 'Walking facilities' was negatively associated with the number of walking trips. With every addition in the score of 'Walking facilities', there would be a decrease by a factor of 0.741 in the number of walking trips. Age is also positively associated with the number of walking trips, meaning older people tend to have more walking trips. The upper part of Table 6-5 (the Poisson regression model) shows that 'Land Use Access' or 'Access to Services' was positively associated with the number of walking trips. An increase in the Access to services perception would lead to an increase by a factor of 1.565 in the number of walking trips. In contrast, perceived 'Walking Facilities' is negatively associated with the number of walking trips. With every addition in the score of 'Walking facilities', there is a decrease by a factor of 0.741 in the number of walking trips. Age is also positively associated with the number of walking trips, meaning older people tend to have more walking trips.

Table 6-5 Association between perceived urban design and walking

Zero-Inflated Poisson regression DV: Number of walking trips inside neighbourhood - N=215					
Model/ IVs	B	Exp(B)	SE	z	p
Poisson regression model					
Age	.012	1.012	.003	3.899	**<.001**
Gender (ref: male)					
Female	.137	1.147	.088	1.556	.120
Education (ref: college/high school or lower)					
University or higher	.078	1.081	.091	.857	.391
Perceived urban design					
Residential Density	.000	1.000	.001	-.707	.479
Land use mix	.010	1.010	.107	.089	.929
Land use access/Access to services	.448	1.565	.160	2.798	**.005**
Street Connectivity	-.121	0.886	.087	-1.392	.164
Walking Facilities	-.300	0.741	.139	-2.168	**.030**
Aesthetics	.140	1.150	.134	1.046	.296
Traffic safety	.092	1.096	.148	.625	.532
Crime safety	.018	1.018	.173	.103	.918
Inflate (logit) model					
Age	-.010	0.990	.043	-.245	.807
Gender (ref: male)					
Female	-1.547	0.213	1.172	-1.320	.187
Education (ref: college/high school or lower)					
University or higher	2.937	18.859	1.555	1.888	.059
Perceived urban design					
Residential Density	.005	1.005	.009	.613	.540
Land use mix	-5.820	0.003	2.653	-2.194	**.028**
Land use access	-1.228	0.293	1.432	-.857	.391
Street Connectivity	7.690	2186.375	2.680	2.869	**.004**
Walking Facilities	2.576	13.144	1.415	1.820	.069
Aesthetics	1.021	2.776	1.743	.586	.558
Traffic safety	-2.388	0.092	1.663	-1.436	.151
Crime safety	-1.929	0.145	1.698	-1.136	.256
Log Likelihood				-369.9308	

Note: boldface font indicates that the coefficient is statistically significant (p>0.05)

6.4 Discussion

6.4.1 The test-retest reliability

The results confirmed the reliability of the NEWS-A-V with moderate to excellent ICCs scores for subscales and individual items. Residential Density and Land Use Mix showed the highest reliability. These two subscales were related to the survey's ability to

transfer the correct meaning of the housing type and land-use destinations which can be attributed to the illustrative pictures accompanying the questionnaire. Adding pictures of residential types and different land-use destinations to the questionnaire increased the reliability of the instrument. Sub-scale Access to Services has the lowest level of reliability. It should be noted that item "difficult to park" of this sub-scale may be less reliable because it may vary by the time of day or during different days of the week; such item was not suitable for point-in-time reliability testing (Oyeyemi et al., 2013).

The test-retest reliability of NEWS-A-V compared well to the findings from the original and adapted NEWS and NEWS-A reliability studies. Reliability scores of NEWS-A-V, in general, were higher than the reliability of the original NEWS, the Australian and Nigerian versions but similar to other versions from Asian countries which share related social and cultural contexts, such as Japan (Inoue et al., 2009), South Korea (Kim et al., 2016) and China (Cerin et al., 2007).

6.4.2 Perceived Urban Design

6.4.2.1 Residential density

Results show that townhouses or row houses are the dominant residential typology while apartments with over 13 stories are the least popular typology. The townhouses (rowhouses), often called 'tube house' in Vietnam, has been the most dominant dwelling typology in Hanoi for centuries (Kien, 2008). The underrepresentation of high-rise apartments is a direct result of the planning restrictions in Hanoi which restricted the height of buildings in most parts of the city other than the new urban areas where high-rise apartment towers are still permitted. In the inner city, houses often have a height of 10-13 meters and only 6-8 meters in the case of the Ancient Quarter (Anh, Thanh, Vu, Ha, & Hung, 2018). Five-stories Soviet-style apartment block is the main dwelling typology in the Collective Housing Quarters but is infrequent in other urban typologies.

6.4.2.2 Land use mix

Among destinations, the participants agreed that coffee places are the most popular destination which tended to always be present within a 5-minute walk from their homes. This result is reasonable when Vietnam is famous for its rich coffee history and culture. In 2019 the country exported $2.39B in coffee, making it the 2nd largest exporter of coffee in the world. The domestic market is also very active, especially in large cities like Hanoi. Coffee shops, coffee stands or beer shops can be found everywhere in Hanoi (see Figure 6-3). They are places for not only enjoying coffee but also working, chatting and

meeting others for personal or business purposes (Zukas, 2020). The convenience of coffee shops makes them an unsubstituted part of Vietnamese daily life (Ta, 2016). Other destinations within walkable distance include convenience/small grocery stores, clothing stores or restaurants. Most participants' workplaces and schools seemed to be far from their homes (more than a 15-minute walk). Hoylyoak and Bray (2015) and Nguyen (2021) found that an average routine work trip travels in Hanoi has an average distance of about 7.2 km, which is equivalent to about a 1-hour walk.

Figure 6-3 Coffee shops and beer shops can be found everywhere in Hanoi.

6.4.3 Access to services

Most participants reported that transit stops (bus stops or metro stations) are easy to access in Hanoi. However, public transport only accounts for 4% of total trips in the present research (see Chapter 5) and below 10% in other studies from Hanoi (JICA, 2007; Pham, 2017). The problem of public transport may not lie only in the availability of the network. A study of 800 students in Hanoi revealed that motorcycle ownership, part-time employment, and fear of sexual harassment (among women only) are some of the reasons that led students to quit riding buses (Nguyen & Pojani, 2022). Participants agreed that stores are within walking distance from home in most neighbourhoods, reflecting the vibrant commercial activities along streets in Hanoi. Participants also reported that it's not difficult to park their vehicles in Hanoi, which seems to be an unexpected result in a

high-dense city like Hanoi. However, it should note that illegal parking is very popular in Hanoi (see figure 6-4), especially in the CBD area (Thanh Truong & Ngoc, 2020; Vu, 2017). A study by Vu (2017) pointed out many reasons for this behaviour including the shortage of parking spaces, low level of enforcement, and high parking charges of the legal parking

Figure 6-4. Parking violations on sidewalks.

6.4.4 Street connectivity

The majority of participants agreed that there are many alternative routes to go from one place to another place in their neighbourhood. hey also believed that the distance between intersections is usually under 100 metres. The main street network of Hanoi is considered to be insufficient for the transport demand (Pham, 2017), but it is supported by the secondary networks of small streets and alleys. Although these dense and complex "narrow-alley" networks are often inaccessible by cars and buses, they provide many alternative routes, significantly reducing the travel times for small vehicles and pedestrians (Nguyen, Kato, & Phan, 2020). However, the alleys network often does not have many intersections and it does have many dead-ends.

6.4.5 Walking facilities

Participants reported that sidewalks are present and well-lit at night in most streets in their neighbourhood. However, they shared the concern that sidewalks are not well maintained and are often obstructed (see Figure 6-5). Sidewalks are usually poorly maintained with uneven surfaces and cracks and gaps (JICA, 2007). In Hanoi, sidewalks are considered a semi-public semi-private space (To, 2011) and are commonly taken over by local people for all kinds of private use, from social meetings to working, playing, or

cooking (Labbé, 2021). Besides, there are also numerous facility-related obstructions on the sidewalk such as electric posts, cables, and electrical cabinets and temporary obstructions such as dumped garbage or construction materials. Although there are periodic "sidewalk clean-up campaigns" carried out by local authorities, these campaigns are often imposed without much flexibility and consideration for real needs of local people, resulting in not meeting the desired efficiency and the sidewalks are repeatedly in a state of disorder (Han, Nguyen, & Sahito, 2019). Participants also reported the common presence of the sidewalk painted line that divides the sidewalk width into two parts: one allows businesses and their parking; the other side is for pedestrians. This line visually reminds people of space for pedestrians, but it is usually violated (Han et al., 2019).

Figure 6-5 The sidewalk is occupied by parked vehicles and personal activities.

6.4.6 Aesthetics

The most remarkable point stated by the participants about the aesthetics in Hanoi is the presence of trees along the streets in most areas, especially in the French Quarter, the Ancient Quarter and the New Urban Areas (see figure 6-5). However, due to the construction of urban transport infrastructure, thousands of trees were cut down and removed from many streets such as Kim Ma, Nguyen Trai and Pham Van Dong, raising concern about pollution and urban heat consequences (Liou, Nguyen, & Ho, 2021). Participants also highlighted that Hanoi has interesting buildings to look at along its streets. The high density of activities and high mixed architecture makes streets and sidewalks in Hanoi diverse, vibrant, and attractive (Ho, Stevenson, Thompson, & Nguyen, 2021). The participants rated Hanoi's urban design as very low for the lack of

natural sight along the streets. Due to rapid urbanisation, it becomes more and more difficult to see natural sights such as rivers, lakes, or large green spaces in most neighbourhoods.

Figure 6-6 Trees on Phan Dinh Phung Street.

6.4.7 Traffic and crime safety.

The worst traffic hazard in the minds of participants was the heavy traffic along their nearby streets. The high volume of traffic often results in serious congestion as well as an increasing level of air and noise pollution, negatively influencing the walking experience. It also increases the risk of collision for pedestrians. However, the heavy traffic also contributed to the slow speed of traffic in the neighbourhood. Participants agreed that exceeding the speed limit was not a problem in their neighbourhoods

The majority of participants had no concern in relation to crime in Hanoi. They agreed that walking is safe throughout Hanoi during the day and at night, which is also supported by the fact that streets are often well-lit at night as confirmed in the result for Walking Facilities. Participants also perceived that the crime rate is low, and it does not discourage them from walking. The heavy traffic and a large number of pedestrians on sidewalks in Hanoi also help to improve crime safety as per the classic concept “eyes on the street” by Jane Jacobs (1961)

6.4.8 Perceived urban design, demographic, and urban typologies.

As reported in Table 6-4, there were minor differences in perceived urban design between males and females except for 'Traffic safety" where females were more concerned than males. Young people perceived higher 'Residential density' than the older ones. Young people often prefer living in high-rise apartments which are more affordable compared to houses and provide utilities that are suitable for the modern and dynamic lifestyle of young people (VNS, 2016).

Regarding the urban typologies, people in all urban typologies perceived a significantly higher land use mix in their neighbourhood than those in New Urban Areas. With the dominance of identical villa and apartments building, New Urban Areas have low-mix land use and long distances to different land-use destinations. Although having lower built-up density and more open spaces, New Urban Areas have more high-rise buildings which were given a higher weight index than houses in the computational process, leading to a high score of perceived residential density. Similarly, Collective Housing Quarter, thanks to the dominance of five-stories Soviet-style apartments and the encroached houses also got a very high score of perceived residential density from people living there. From Table 6-3, participants from French Quarter rated their neighbourhoods have the best land use mix. The French Quarter has many public buildings such as government offices, hospitals, theatres, cinemas, representative offices, libraries, and post offices, and at the same time, many commercial buildings such as hotels, restaurants, coffee shops, shops, malls due to it located in the city centre. The same pattern repeated with 'Access to services' where New Urban Areas have a significantly lower score than other urban typologies. Participants in New Urban Areas reported they did not have adequate services within a proximity distance. In New Urban Areas, the traditional shops are often replaced by shopping malls, which can provide the neighbourhoods with a non-polluted shopping indoor environment, but at the same time, they reduce the level of 'Access to services as well as the social environment of the streets there (Bäckman & Rundqvist, 2005). However, New Urban Areas did have a significantly higher perceived 'Walking Facilities' and 'Street connectivity' than urban typologies, thanks to their well-designed infrastructure with a grid-like network of main roads and internal streets which are usually equipped with spacious and beautiful sidewalks. However, the good transport infrastructure here seemed to simulate drivers exceeding their speeds in most streets, resulting in a lower rate of 'Traffic Safety' from people in New Urban Areas compared to Ancient Quarter, French Quarter and Collective Housing Quarters.

6.4.9 Associations between Perceived Urban Design and Walking

The results show that perceived Land Use Mix and Access to Services play a more important role than Street Connectivity and Walking Facilities in promoting the prevalence of walking. Well-mixed land use offers a broad range of services in an area, increasing the proximity between destinations, thereby shortening trip distances and promoting active transport (Cervero & Kockelman, 1996; Frank, 2000). Several studies show that mixed-use supports walking (Christiansen et al., 2016; Eriksson, Arvidsson, Gebel, Ohlsson, & Sundquist, 2012; Frank, Schmid, Sallis, Chapman, & Saelens, 2005) and cities in Asia like Hanoi often have high land use mix than Western Cities (Chen et al., 2020). On the other hand, having good and adequate walking facilities and a high level of street connectivity are usually believed to be the factors that encourage people to walk, however, these factors may not mean much if the neighbourhood does not have well-mix land use and high accessibility to services because people do not have enough destinations to walk to and end up using motorised vehicles to go to the farther locations in order to access their desired services. These results are also relevant to finding from previous sections and chapters regarding the five urban typologies in Hanoi. For example, section 6.3.8 shows that people perceived significantly better walking facilities as well as a higher level of street connectivity in New Urban Areas than in other urban typologies, due to the fact that these areas are often formally designed with a grid-like street network and high-quality and adequate walking infrastructure such as sidewalks, pedestrian lightings, crosswalk and signal. However, New Urban Areas have limited services and low-mixed land use with the dominance of residential buildings. Findings from Sub-study 1 in Chapter 5 confirmed people in New Urban Areas have the least number of walking trips but the longest average walking time per trip. They do have to walk long distances to reach their desired services, which may also discourage them from engaging in walking. This finding suggests urban designer to design the neighbourhood that more mixed-use with easy-to-access services rather than just focusing on delivering appealing network of streets and walking facilities.

6.5 Summary

This chapter presented the development and validation of NEW-S-V tool in Hanoi. It confirmed the reliability of the NEW-S-V and the relationship between the perceived urban design and walking behaviour. The perceived urban design varies across the urban typologies with the New Urban Areas having significantly lower ‘Land use mix’, ‘Access

to services' but higher 'Residential Density', 'Walking Facilities' and 'Street connectivity' compared to other urban typologies. Results from the statistical analysis show that 'Land use mix' and 'Access to services' are positively associated while 'Walking Facilities' and 'Street connectivity' is negatively associated with the possibility of engaging in walking and the number of walking trips, highlighting the role of mix land use in promoting walking. Based on the results of the present study, we expect that the NEW-S-V scale can be used as an appropriate method to collect perceived urban design data in Vietnam with future studies able to apply the instrument to explore the relationship between urban design and walking behaviour, providing useful findings for planning policies and strategies as well as implementing interventions that promote walking.

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CHAPTER 7 URBAN DESIGN QUALITIES, THE WALK SCORE AND ENVIRONMENTAL FACTORS

7.1 Introduction

As highlighted in Chapter 2, an important finding from the literature is considerable variation in the factors of the built environment reported to be important contributors to walking(Brownson, Hoehner, Day, Forsyth, & Sallis, 2009). In the macro-scale, the most well-known built environment variables are the 3Ds (density, diversity, and design) first used by Cervero and Kockelman (Cervero & Kockelman, 1996). These factors were added to expanding to the 5Ds by including destination accessibility and distance to transit (Ewing & Cervero, 2010). Due to the objectiveness of these attributes, there is an extensive description of these factors in the literature on the study of urban environments. However, D variables are insufficient to represent the success of the urban environment in terms of facilitating physical activity (Sallis et al., 2011). The gross characteristics of street networks such as intersection density and block size, which are used to calculate the Design variable, may not affect the experience of people using the street as much as the micro-features of the streets (Ewing, Hajrasouliha, Neckerman, Purciel-Hill, & Greene, 2015). The macro variables should, therefore, be supplemented by subtle qualities of the street environment for a better understanding of the impact of the urban design.

Conversely, micro-scale studies of the urban environment, alone, investigate the physical features and urban design qualities at the street level. The classic urban design literature presents many theories and concepts related to street-level urban design such as “imageability” by Lynch (Lynch & Studies, 1960), "eyes on the street" by Jacobs (Jacobs, 1961), "liveable streets" by Appleyard (Appleyard, Gerson, & Lintell, 1981), or "soft edges" by Gehl (Gehl, 1987). Although this literature emphasizes the importance of micro-scale urban design, few studies have reported the empirical evidence and little description of systematic measuring instruments one could use to support and validate the varied theories. Recent studies on micro-scale urban designs have focused on developing measurement tools. Perceived and objective measures are often referred to as measures needed in urban design measurement tools. Perceived measures, report a residents' perception of their surrounding urban design using interviews or self-administered questionnaires. Objective measures often investigate physical features of streets (sidewalk width, presence of the sidewalk, crosswalks, traffic lights, building height,

traffic volume, trees) using audit tools. However, the perceived measures often face issues of measurement reliability (Kim, Park, & Lee, 2014). On the other hand, physical attributes collected from objective measures may not reflect "people's overall perceptions of the street environment " and perceptual qualities of the urban design are difficult to measure objectively (Ewing & Handy, 2009). Taking these limitations into account, only a few tools including the tool developed by Ewing et al (2006) have been able to overcome the lack of objectiveness in measuring perceived urban design qualities. The "Walk Score" developed by Kocher, Lerner & Mathieu (2007) is an effective, convenient, and reliable measure to quantify walkability at the micro-scale (Duncan, Aldstadt, Whalen, & Melly, 2013; Sun, Lu, & Sun, 2021)

Despite the significant effort in developing measurement tools for micro-scale urban design, there are few studies in this field due to the considerable time and cost required to develop such tools (Steinmetz-Wood, Velauthapillai, O'Brien, & Ross, 2019). This also explains why there are so few micro-scale urban design studies emanating from low- and mid-income countries in Asia. However, there are opportunities to apply measurement tools such as the Walk-Score, which have only been applied in high-income cities to cities in Asia. Most cities in low and middle-income countries in Asia are now undergoing rapid urban development (Chen, Chiu, & Lin, 2020). Hence, there are valuable opportunities to develop or adopt a better urban design that supports active lifestyles and promotes sustainability. Research to fully understand the impact of characteristics of micro-scale urban design is essential to develop suitable urban design policies and strategies. In addition, in low- and middle-income countries, the micro-scale urban research approach is often ideal as opposed to macro-scale approaches for many reasons. Firstly, fine-grained geographical data, which is still challenging to access even in high-income countries, are often insufficient, inconsistent, or not available and are costly to attain in low- and middle-income countries (Koohsari et al., 2021). Secondly, urban forms in low and middle-income countries throughout Asia such as Vietnam are often high density with a vibrant mix of uses (Chen et al., 2020), which usually come from historical fluctuations and unregulated development rather than official planning (Storch, Eckert, & Pfaffenbichler, 2008). Therefore, focusing on analysing micro-scale urban design, instead of studying macro-scale variables such as density and diversity, will assist our understanding. More importantly, the micro-scale characteristics of the pedestrian environment can be modified at a lower cost and in a shorter time frame than

reconfiguring the macroscale design (Cain et al., 2014), which fits the rapid and fragmented urban development and the limited resources of those countries.

In addition, environmental factors like weather and pollution may influence walking behaviour largely, especially in developing countries where the level of pollution is often higher (WHO, 2021). Hence, research to quantify those factors and identify their impacts on walking is essential in such conditions.

The present chapter describe in detail two sub-studies. Sub-study 3 assesses the urban design qualities across the various urban typologies identified within Hanoi using tools such as Urban Design Qualities Measurement and Walk Score. In addition, Sub-study 4 measured environmental factors including temperatures, humidity, and air and noise pollution are and analysed to assess their influence on walking in Hanoi.

7.2 Methods

Methods for these studies (Sub-study 3 and 4) were described in section 4.5 and section 4.6 of Chapter 4. The five urban design typologies are Ancient Quarter, French Quarter, Collective Housing Quarters, Urbanised Village Areas, and New Urban Areas. These urban design typologies are identified and described in section of Chapter 3 and section of Chapter 4.

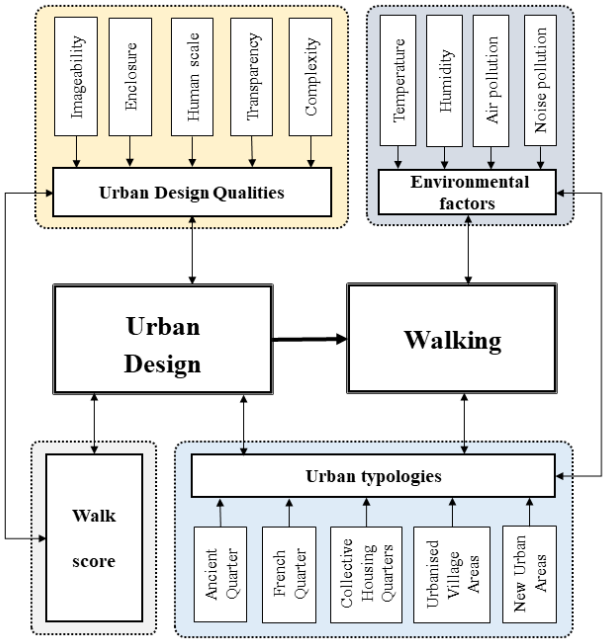

Figure 7-1 Research framework of Sub-study 3 & 4

7.3 Results

7.3.1 Urban design qualities

7.3.1.1 Urban design qualities in Hanoi

The mean recorded values and associated scores for the individual items, the five urban design qualities and the total combined urban design quality score for the five urban typologies are summarised in Table 7-1. The Z-score for the individual and total combined urban design qualities by the urban typologies is illustrated in Figure 7-2.

Figure 7-2 Z-score of individual and total combined urban design qualities for five urban typologies.

Table 7-1 Mean scores for individual items and urban design qualities for five urban typologies and the whole of Hanoi.

	Urban typologies and individual items	Urbanised Village Areas	Collective Housing Areas	Ancient Quarter	French Quarter	New Urban Areas	Hanoi
	Total urban design quality score	24.95	23.53	30.32	22.95	17.84	23.92
Imageability	1. number of courtyards, plazas, and parks [a]	*0.15*	**1.64**	0.26	0.67	0.77	0.70
	2. number of major landscape features [a]	*0.00*	**0.18**	0.09	0.09	*0.00*	0.07
	3. proportion historic building frontage [a]	*0.00*	*0.00*	0.16	**0.33**	*0.00*	0.10
	4. number of buildings with identifiers [a]	2.72	1.61	**5.90**	2.09	*1.31*	2.73
	5. number of buildings with nonrectangular shapes [a]	1.93	*1.10*	**2.25**	1.68	2.06	1.80
	6. presence of outdoor dining [b]	**0.64**	**0.64**	**0.64**	**0.64**	0.24	0.56
	7. number of people [b]	0.25	0.23	**0.44**	0.23	*0.11*	0.25
	8. noise level [a]	-0.63	-0.56	*-0.74*	-0.63	**-0.41**	-0.59
	Total imageability score	7.50	7.28	**11.43**	7.54	*6.52*	8.05
Enclosure	1. number of long sight lines [a]	**-0.08**	-0.39	-0.50	-0.43	*-0.89*	-0.46
	2a. proportion street wall [b]	0.57	0.49	**0.62**	0.54	*0.41*	0.53
	2b. proportion street wall [c]	0.76	0.65	**0.81**	0.66	*0.58*	0.69
	3a. proportion of sky ahead	**-0.36**	-0.51	-0.51	-0.60	*-0.96*	-0.59
	3b. proportion of sky across	-0.16	-0.25	**-0.07**	-0.23	*-0.47*	-0.24
	Total enclosure score	**3.30**	2.55	2.91	2.51	*1.24*	2.50
Human scale	1. number of long sight lines [a]	**-0.19**	-0.93	-1.20	-1.02	*-2.13*	-1.09
	2. proportion windows at street level [b]	0.50	0.72	**0.96**	0.58	*0.32*	0.61
	3. average building height [b]	**-0.03**	*-0.04*	-0.03	-0.03	-0.04	-0.03
	4. number of small planters [b]	*0.18*	**0.65**	0.31	0.29	0.24	0.34
	5. number of street furniture and other items [b]	*0.29*	**0.69**	0.46	0.59	0.35	0.47
	Total human scale score	3.36	**3.70**	3.10	3.02	*1.35*	2.91
Transparency	1. proportion windows at street level [b]	0.55	0.79	**1.07**	0.64	*0.35*	0.68
	2. proportion street wall [b]	0.53	0.45	**0.58**	0.50	*0.39*	0.49
	3. proportion active uses [b]	0.28	**0.48**	0.47	0.31	*0.12*	0.33
	Total transparency score	3.07	3.44	**3.83**	3.17	*2.56*	3.21
Complexity	1. number of buildings [a]	2.44	*0.88*	**2.75**	1.16	1.51	1.75
	2a. number of basic colours [a]	0.92	1.01	**1.12**	0.95	*0.89*	0.98
	2b. number of basic accent colours [a]	0.95	1.29	**1.43**	1.23	*0.84*	1.15
	3. presence of outdoor dining [b]	**0.42**	**0.42**	**0.42**	**0.42**	*0.16*	0.37
	4. number of pieces of public art [a]	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	5. number of people [b]	0.37	0.35	0.72	0.35	*0.16*	0.39
	Total complexity score	7.71	6.56	**9.04**	6.72	*6.17*	7.24

Overall, Hanoi had a mean combined score of urban qualities of 23.92 with the Ancient Quarter having the highest total combined score at 30.32, followed by the Collective Housing Quarter, the French Quarter and the Urbanised Village Area at 25.11, 23.77 and 23.16, respectively. The New Urban Area had the lowest total score of urban design quality at 17.94. In terms of the individual urban design qualities, Hanoi had the score of Imageability, Enclosure, Human Scale, Transparency, and Complexity of 8.05, 2.50, 2.91, 3.21, and 7.24, respectively. When assessing each urban typology, Imageability quality placed the Ancient Quarter at the top with a score of 11.43, being the only urban typology that has an Imageability score above 8. In contrast, the New Urban Area was the only urban typology that had an Imageability score below 7, which was the lowest score among all urban typologies. For Imageability contributors, the Collective Housing Quarter had the highest number of courtyards, plazas, and parks but the lowest number of non-rectangular-shaped buildings. The Ancient Quarter had the greatest number of buildings with identifiers and people on the street, and at the same time, the highest level of noise. For Enclosure, the Urban Village Area ranked highest in terms of Enclosure with a score of 3.30 which was 2.6 times higher than the Enclosure score for the New Urban Area (1.24) and 1.3 times higher than the Enclosure score of the French Quarter (2.51). For Enclosure contributors, The Ancient Quarter and Urbanised Village Area had the best scores for the proportion of street wall and sky view while New Urban Area had the lowest one. In terms of Human Scale and Transparency, the New Urban Area had the lowest scores of 1.35 and 2.56, respectively, while the remaining urban typologies both scored above 2 for Human Scale and above 3 for Transparency. For Human Scale contributors, the Collective Housing Quarter had the most street furniture and small plants. For Transparency, the Ancient Quarter had 60% of windows at the street level which is the highest while the Collective Housing Quarter had more than 90% of ground level that is active. The Ancient Quarter was the only urban typology that had a score above 8 for Complexity (9.04) followed by the Urbanised Village Area at 7.72. The other three urban typologies: New Urban Area, Collective Housing Quarter and French Quarter all had Complexity below 7 at 6.17, 6.56 and 6.72, respectively. For Complexity contributors, all most urban typologies had the presence of outdoor dining but none of them had the presence of public art.

7.1.1.1 Number of pedestrians and Urban design qualities

The regression (simple linear regression) modelling of the number of pedestrians by the combined urban design quality scores highlighted a significant association between the urban design qualities and the number of pedestrians observed on the streets (see Figure 7-3)

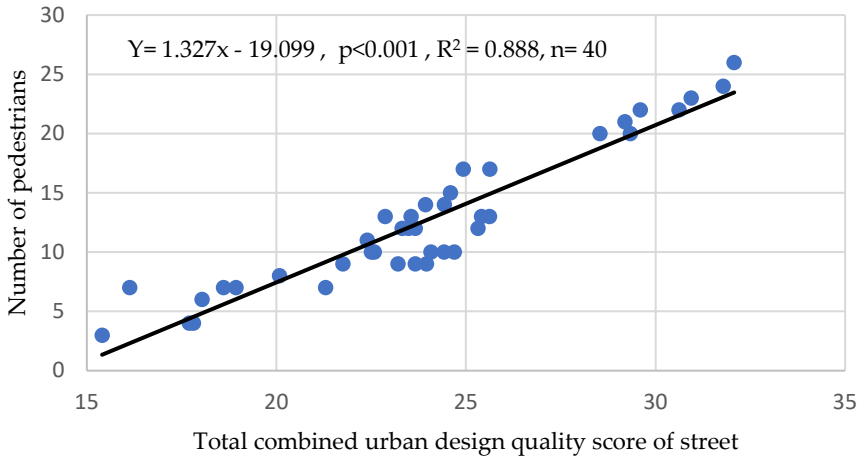

Figure 7-3 Correlation between number of pedestrians on the street and total combined urban design quality score of streets

7.1.1.2 Associations between Urban Typologies and Urban Design Qualities

Table 7-2 highlights the findings from the regression analysis assessing the associations between the five urban typologies and the five urban design qualities. Compared with streets in the Urbanised Village Area (the reference urban typology), streets in the Ancient Quarter had significantly higher Imageability scores. For Enclosure, both the Collective Housing Quarter and the French Quarter had substantially lower scores than the reference typology. The human scale was not considerably different across urban typologies except for the New Urban Area. Streets in the Urbanised Village Area had a lower level of Transparency than those in the Ancient Quarter and the Collective Housing Quarter, and a higher Complexity score compared with the other urban typologies other than the Ancient Quarter. The Urbanised Village Area had significantly higher scores across all five urban design qualities in comparison with the New Urban Area. The total urban design quality score of the Urbanised Village Area was significantly higher than the New Urban Area but substantially lower than the Ancient Quarter.

Table 7-2 Associations between Urban Typologies and Urban Design Qualities

Urban typology	Imageability	Enclosure	Human Scale	Transparency	Complexity	Total score
Ancient Quarter	**0.857**	-0.199	-0.114	**0.655**	**0.464**	**0.516**
	(p < 0.001)	(p = 0.050)	(p = 0.242)	**(p < 0.001)**	**(p < 0.001)**	**(p < 0.001)**
Collective Housing	-0.052	**-0.385**	0.146	**0.321**	**-0.433**	-0.146
Quarter	(p = 0.470)	**(p < 0.001)**	(p = 0.136)	**(p = 0.001)**	**(p < 0.001)**	(p = 0.105)
French Quarter	0.017	**-0.409**	-0.151	0.087	**-0.360**	**-0.190**
	(p=0.811)	**(p < 0.001)**	(p = 0.125)	(p=0.348)	**(p < 0.001)**	**(p = 0.001)**
New Urban Area	**-0.217**	**-1.057**	**-0.885**	**-0.439**	**-0.561**	**-0.692**
	(p<0.010)	**(p < 0.001)**	**(p < 0.001)**	**(p < 0.001)**	**(p < 0.001)**	**(p < 0.001)**
R-Squared	0.890	0.789	0.798	0.818	0.861	0.936

Note: Boldface font indicates that the coefficient is statistically significant.
Urbanised Village Area is the reference urban typology

7.1.1.3 Urban design comparison of four cities

Table 7-3 outlines the mean score of five urban design qualities and the total score for New York, Brisbane, Gurgaon and Hanoi. Gurgaon has the highest total combined urban design quality scores at 25.54 followed closely by Hanoi at 23.92. At a much lower level, New York and Brisbane share similar total scores of 17.04 and 17.69, respectively. Despite having both levels of Imageability quality and Complexity above 10, Gurgaon's score of Enclosure quality is only 0.93 which is the lowest among the four cities. Brisbane ranks first in Transparency quality, just 0.07 points above Hanoi.

Table 7-3 The individual and the total combined score of urban design qualities for New York, Brisbane, Gurgaon, and Hanoi

Urban design quality	New York (USA)	Brisbane (Australia)	Hanoi (Vietnam)	Gurgaon (India)
Imageability	3.58	4.68	8.05	10.01
Enclosure	3.06	2.09	2.50	0.93
Human scale	2.93	3.21	2.91	1.69
Transparency	2.66	3.28	3.21	2.84
Complexity	4.81	4.43	7.24	10.07
Total score	17.04	17.69	23.92	25.54

7.3.2 Walk score, temperature, humidity, air pollution and noise pollution

The Walk Score is positively correlated with three urban design qualities namely Imageability, Transparency and Complexity (see Table 7-4). Walk Scores of streets in Hanoi ranged from 80 to 100, being highest in the Ancient Quarter (mean=92.25) and lowest in New Urban Area (mean=85.37) (see Table 7-5). Those scores were equivalent to the "Very Walkable" and "Walker's Paradise" levels on the Walk Score scale. Compared with streets in the New Urban Areas (the reference urban typology), streets in the Ancient Quarter, French Quarter, and Collective Housing Quarter had significantly higher Walk Scores (see Table 7-6). The Walk Score was also positively correlated with the number of pedestrians on the streets (see Table 7-7).

Table 7-4 Pearson correlation between Walk Score and individual urban design qualities

					95% CI	
Urban design quality	B	SE	t	p	LCI	UCI
Imageability	3.086	.890	3.466	**.001**	1.277	4.896
Enclosure	.588	1.325	.444	.660	-2.104	3.281
Human scale	1.418	1.217	1.166	.252	-1.054	3.891
Transparency	5.161	2.515	2.052	**.048**	.049	10.272
Complexity	-3.972	1.433	-2.772	**.009**	-6.883	-1.060

Note: Boldface font indicates $p < 0.05$

The temperatures observed on the streetside in Hanoi on the survey day ranged from 26.93°C to 31.20°C, with the temperature highest in the Urbanised Village Areas (mean=30.59°C) and lowest in the New Urban Area (mean=28.33°C) (see Table 7-5). Streets in the Ancient Quarter and the Urbanised Village Areas had significantly higher temperatures than streets in the New Urban Areas (the reference urban typology) (see Table 7-6). There was no association between the temperature observed on the street and the number of pedestrians on the streets (see Table 7-7).

Table 7-5 Mean values of Walk Score, temperature, humidity, (air pollution) PM2.5, noise pollution (LAeq) on streetside for five urban typologies.

Urban typology	Walk Score	Temperature (°C)	Humidity (%)	Pm2.5 (µg/m3)	LAeq (dB)
Ancient Quarter	**99.25**	29.17	68.42	73.53	**75.08**
French Quarter	97.37	28.78	73.31	56.47	69.95
Collective Housing Quarter	95.25	28.74	69.11	67.49	66.61
Urbanised Village Area	87.37	**30.59**	*67.01*	**76.34**	72.84
New Urban Area	*85.37*	*28.33*	**73.89**	*43.84*	*55.53*

Note: Boldface text: max, Italic text: min

Humidity was also attained on the survey day. Humidity on the streets of Hanoi ranged from 62.22% to 79.10%, being highest in the New Urban Areas (mean=73.89%) and lowest in the Urbanised Village Areas (mean=67.01%) (see Table 7-5). Compared with streets in the New Urban Areas (the reference urban typology), the humidity of streets in the Ancient Quarter, Collective Housing Quarter and Urbanised Village Areas were significantly lower (see Table 7-6). Humidity was negatively correlated with the number of pedestrians on the streets (see Table 7-7).

Table 7-6 Correlation between urban typologies and Walk Score, temperature, humidity, (air pollution) PM2.5, and noise pollution (LAeq) on streetside.

Urban typology	Walk Score	Temperature	Humidity	PM2.5	LAeq
Ancient Quarter	**13.875**	**0.838**	**-5.479**	**29.696**	**19.550**
	(p < 0.001)	**(p =0 .037)**	**(p = 0.002)**	**(p = 0.005)**	**(p < 0.001)**
French Quarter	**12.000**	0.442	-0.581	12.630	**14.425**
	(p < 0.001)	(p = 0.260)	(p = 0.725)	(p = 0.210)	**(p < 0.001)**
Collective Housing Quarter	**9.875**	0.405	**-4.787**	**23.654**	**11.087**
	(p < 0.001)	(p =0 .302)	**(p = 0. 006)**	**(p=0.022)**	**(p < 0.001)**
Urbanised Village Area	2.000	**2.254**	**-6.889**	**32.509**	**17.312**
	(p = 0.123)	**(p < 0.001)**	**(p < 0.001)**	**(p = 0.002)**	**(p < 0.001)**
R-Squared	0.845	0.538	0.445	0.295	0.949

Note: Boldface font indicates p < 0.05

Air pollution ($PM_{2.5}$) on the streetside in Hanoi ranged from 31.23 µg/m3 to 134.17 µg/m3. The level of $PM_{2.5}$ was highest in Urbanised Village Areas (mean=76.34 µg/m3) and lowest in New Urban Areas (mean=43.84 µg/m3) (see Table 7-5). Streets in the Ancient Quarter Collective Housing Quarter and Urbanised Village Areas had a significantly higher level of $PM_{2.5}$ on the streetside than streets in the New Urban Areas (the reference urban typology) (see Table 7-6). The level of $PM_{2.5}$ did not correlate with the number of pedestrians on the streets (see Table 7-7).

Table 7-7 Pearson correlation between the number of pedestrians and Walk Score, temperature, humidity, air pollution ($PM_{2.5}$), noise pollution (LAeq) on streetside.

			95% CI	
Parameters	r	p	LCI	UCI
Walk Score	0.693	**<.001**	0.525	1.000
Temperature	0.180	0.133	-0.088	1.000
Humidity	-0.300	**0.030**	-1.000	-0.039
PM2.5	0.980	0.273	-0.170	1.000
LAeq	0.680	**<.001**	0.511	1.000

Note: Boldface font indicates $p < 0.05$

On the survey day, noise levels (LAeq) on Hanoi's streets ranged from 51.5 dB to 76.7 dB, being highest in Ancient Quarter (mean=75.08 dB) and lowest in New Urban Area (mean=55.53 dB) (see Table 7-5). Compared to streets in the New Urban Areas (the reference urban typology), all other urban typologies had a significantly higher level of noise on the streetside (see Table 7-6). The noise level was positively correlated with the number of pedestrians on the streets (see Table 7-7).

7.4 Discussion

7.4.1 Urban design qualities

Overall, Hanoi had remarkably high urban design qualities across the city. According to the results, streets in the areas sharing the same urban typology tended to have similar scores of urban design qualities even though their locations were considerable distances apart. The finding suggests that unique urban typologies have an impact on the quality of urban design. Therefore, the focus of the discussion relates not to the urban design qualities of individual streets but rather, to address the variation of the five urban design qualities across the urban typologies studied.

7.4.1.1 Imageability

The differences in the Imageability scores between the urban typologies are substantial. As expected, the Ancient Quarter (the tourist centre for Hanoi) had a vast number of people on the street and many unique shops, restaurants and hotels reflecting the high density of commercial activity which led to a high score for building identifiers and on-street people. The Imageability of the Ancient Quarter is also boosted by the distinct architecture comprising a mix of ancient houses with modern residential and commercial buildings. In contrast, the French Quarter, the Collective Housing Quarters, and the Urbanised Village Areas comprise both positive and negative features providing a balanced Imageability score. For example, the Collective Housing Quarters has numerous community courtyards but for identifiers and unique shape, the scores are low as a consequence of the rectangular-shaped buildings which are typical characteristics of the Soviet-style apartment blocks. These apartment blocks are usually renovated informally with many extended structures to create extra rooms that are locally called "chuong cop" (tiger cages) (Phuong & Groves, 2011)

Despite lacking open spaces, the Urbanised Village Areas have a large number of nonrectangular-shaped buildings due to the high building density and the popularity of unregulated self-built dwellings in these locations. The French Quarter attains a good score for imageability due to the heritage French colonial architecture; however, the process of conservation, privatization, and commercial redevelopment, both formally and informally, have changed the structure and appearance of these buildings significantly (To & Chong, 2013). New Urban Area ranks as the poorest for Imageability. Although having a low noise level and a lot of open spaces, the urban design in these areas is generic and unmemorable. The dominance of private residential townhouses and villas leads to few people and activities on the streets. Walk Score are higher in

Overall, the positive features of the Imageability of Hanoi are the mixed architecture and the vibrant streets that reflect through a large number of nonrectangular-shaped buildings with people on the street as well as the presence of outdoor dining across most urban typologies. However, reduced urban design qualities are attributed to the lack of open spaces which is a consequence of the traditional compact urban form, as well as the recent densification leaving few green open spaces (Mauro, 2020). The vibrant atmosphere on the street across the various urban typologies makes the neighbourhoods memorable but simultaneously creates considerable noise, which reduces the

Imageability quality. The noise pollution in Hanoi is predominantly the result of high-volume and congested traffic, to which poor urban design is one of contributing factors.

7.4.1.2 Enclosure

The high-density urban form in Hanoi enhances the Enclosure design quality significantly. The Urbanised Village Area is the leading typology with respect to this design quality feature. The Urbanised Village Areas feature an organic street pattern characterized by small streets and alleys that "start and end, curve back and forth, seemingly at random" (Munson, 2013). Although the building height is limited in these areas, the high density of houses together with the system of narrow streets and alleys create a high proportion of street walls and a low proportion of sky view, resulting in a room-like quality for spaces.

In contrast, the New Urban Areas have few street walls, but they do have a high sky view due to the wide roads and pavements, large setbacks and breaks in visual continuity with many gaps between buildings. The gaps can be either "soft gaps", defined as open spaces between buildings like frontal or surrounding yards and gardens, or "hard gaps" that are unused lots or spaces (Bereitschaft, 2017). While irregular street layouts in Urbanised Village Areas can result in visual termination points that enhance the sense of enclosure, rectilinear street patterns in New Urban Areas create many long sight lines that undermine the sense of enclosure significantly (Ewing & Clemente, 2013).

7.4.1.3 Human Scale

There are few differences in scores for the Human Scale design quality across the urban typologies in Hanoi. This finding is explained by the reduced height of buildings and the high number of small planters and street furniture. This is a direct result of the planning restrictions in Hanoi which restricted the height of buildings in most parts of the city other than the New Urban Areas where high-rise apartment towers were, and still are, permitted. In the inner city, houses often have a height of 10-13 meters and only 6-8 meters in the case of the Ancient Quarter (Anh, Thanh, Vu, Ha, & Hung, 2018). The two-story façade of tube houses, which are the most popular dwelling typology in the Ancient Quarter, offers ideal conditions for audio-visual communication between the residents and people from the street, creating a very human-scaled streetscape (Kien, 2008).

Since there are limited open spaces in a dense city like Hanoi, people use streets and sidewalks as temporary extensions of their small living spaces, which makes each street very lively. Having a vibrant street life, street furniture and small planters are often

set up informally. Sidewalks are considered semi-public semi-private spaces (To, 2011) and are used for all kinds of activities from social meetings to working, playing, cooking or even bathing children. That multi-functional dimension is unique to Asian streets and opposes the concept of one-space one-function which is prevalent in Western urban design (Mateo-Babiano & Ieda, 2005).

Despite the minimal variation between urban typologies, the Urbanised Village Areas still stand out in terms of the quality of the Human Scale, followed by the Ancient Quarter. Although suffering from traffic congestion, streets in the Ancient Quarter are traditionally well proportioned to the human body since they are originally designed for walking during the feudal periods. In other settings, street networks and urban design in the Urbanised Village Areas were not planned or designed and sometimes are established, informally. Despite this, they still fit the human form due to the nature of any informal system that is to serve the most basic daily human activities. The absence of long sight lines in Urbanised Village Areas also contributes to the high Human Scale quality of this urban typology.

7.4.1.4 Transparency

There are only minor differences in Transparency design scores across the five urban typologies except for the New Urban Area. Although Hanoi doesn't have a regulation for street-level windows like other cities, the dominance of shophouses (Davis, 2012) and very high commercial activities across the city, resulting in a high proportion of windows at the street level (61%) which increases the design quality - Transparency. Due to the narrow width of street houses, shop facades are open to the street to encourage entry, and at the same time, create a high degree of ground-level transparency between indoors and out. Each shop becomes the "social window" (Bäckman & Rundqvist, 2005) that opens up to the social platform which is the front street. Shop owners and people on the street can easily have visual-audio communication that sometimes happens from the opposite sides of the street (Kien, 2008). However, due to the increasing level of noise and air pollution in Hanoi, glass walls have been used extensively. Although the use of glass facades reduces the social aspect to some extent, the transparency in the form of windows and open doorways still remains (Bäckman & Rundqvist, 2005).

On the other hand, high solid walls or fences around large government buildings and private residential villas in the French Quarter and the New Urban Areas reduce the Transparency quality significantly. In New Urban Areas, the traditional shops are often

replaced by shopping malls, which can provide the neighbourhoods with a non-polluted shopping indoor environment, but at the same time, they reduce the Transparency quality as well as the social environment of the streets there (Bäckman & Rundqvist, 2005).

7.4.1.5 Complexity

As with most of the design qualities, the Ancient Quarter scored highest in the design quality Complexity. Due to the intense densification of Hanoi in relation to the built environment and population density, and the dominance of narrow tube houses, the total number of buildings on each street in the Ancient Quarter is significant. In addition, the mixed architecture and land use, together with the development of tourism services in the Ancient Quarter. Buildings and shops exhibit numerous basic and accent colours to attract customers that mostly are tourists. As expected from a centre of tourism, a high number of pedestrians were observed on the streets in the Ancient Quarter, contributing to the sense of complexity (see Figure 7-4).

Figure 7-4 Vibrant streets in the Ancient Quarter

In contrast, the New Urban Areas scored lowest. With the original intent to provide an orderly streetscape, uniform designs have been applied to the houses and buildings in these areas creating very few types and identical building designs (Tran, 2014), which

have reduced the sense of Complexity. Furthermore, the low built-up density together with the presence of many open spaces has lowered the score of the number of buildings.

A noticeable negative factor for complexity quality is the absence of public art in all studied areas, which might be due to inadequate arts infrastructure, the lack of funding and resources, and stringent government censorship (Brittney, 2013). In contrast, outdoor dining is present in most studied areas, thanks to Hanoi's unique street food market and lifestyle, which plays a central role in both culture and informal economy (Atomei, 2017).

7.4.1.6 Comparing the urban design qualities of Hanoi with other cities.

Based on the total scores from five urban design qualities, four cities can be divided into two pairs: i) Hanoi and Gurgaon and ii) New York and Brisbane, which suggests that cities in the same pair have similar urban design. This finding also reflects the fact that Hanoi and Gurgaon are both cities in low- and middle-income countries in Asia, while Brisbane and New York are cities from high-income countries which follow the typical Western-style urban planning. The pairs of cities are also in line with the result of a study by Thompson et al. (Thompson et al., 2020) on urban design types and road transport injuries across the world. In that research, North American cities like New York and Australian cities like Brisbane are classified into the cluster of urban designs named "Motor City" characterized by low-density urban form, and grid-based road networks, while Indian cities like Gurgaon and Vietnamese cities like Hanoi are classified into the cluster of urban design named "Informal City" characterized by low capacity informal road networks and low rail transportation (Thompson et al., 2020).

In another highlight, the Imageability and Complexity scores of Gurgaon and Hanoi are significantly higher than those of New York and Brisbane. By analysing the original studies (Ewing & Clemente, 2013; Hooi & Pojani, 2020; Khetrapal & Chadchan, 2019), these differences can be explained by the fact that Gurgaon and Hanoi have a high number of pedestrian movements and activities on the street, which are important elements contributing to both imageability and complexity qualities. In contrast, despite being one of the most walkable cities in the US, streets in New York only have an average of 5.64 pedestrians on the observer side in the study by Ewing and Clemente (Ewing & Clemente, 2013). In contrast to Western cities, the lively street life existed naturally in the Asian urban context and was established by numerous aspects such as socio-cultural attributes, the need-hierarchy, psyche and movements, diversity of street use, informal street use, and pedestrian culture (Mateo-Babiano & Ieda, 2007). While individualism is popular in

cultures of Western Europe and North America, collectivism is typical in cultures of Asia, Africa, and parts of Europe and Latin America (Triandis, 2015). People in Asia often have more open character and require lower privacy than Westerners, which explains their willingness to participate in common activities on the street. Even in the Vietnamese language, streets and roads are called as “con pho” and “con duong” with the “con” being a classifier word for living things, opposing the inanimate objects that are “cai” (Gibert & Son, 2016).

The comparison between the four cities has managed to show parts of the differences in urban design qualities between cities in low- and high-income countries as well as between Asian cities and Western cities. However, it’s also important to note that such a comparison may contain some errors because of the considerable differences in the study objectives, the size of the samples studied and the operationalization of the tool by Ewing et al. (2006) in the chosen studies. The limited number of studies and geographical locations of the studied cities reduce the ability to robustly compare differing urban models and urban contexts, such as those found in European cities.

7.4.2 Walk Score

The result shows that Walk Score was significantly correlated with multiple urban design qualities including Complexity, Imageability. This result is expected since Walks Score is based on the proximity of destinations and those urban design qualities are calculated by the number of destinations such as parks, plazas, number landscape features, outdoor dining, public arts or historic buildings. Conversely, Walk-Score is not associated with Human Scale and Enclosure since they are based on the proportion and size of buildings and streetscape which has nothing related to destinations. Those findings are consistent with previous studies which also showed Walks Score to be associated with the availability of destinations (Carr, Dunsiger, & Marcus, 2011; Koohsari et al., 2018). Walk Score was also found to be significantly correlated with Transparency although this urban quality is not a destination-based measure. It may be due to the reason that streets with a lot of destinations such as shops and restaurants often have transparent and accessible storefronts for displaying products and attracting more customers, thereby having a high proportion of windows on the façade. Walks Score was also found to be higher in the Ancient Quarter, French Quarter, and Collective Housing Quarter thanks to their well-mix land use, and lower in New Urban Areas due to the dominance of residential buildings and the lack of local destinations. Furthermore, the result also shows

that Walk Score was significantly correlated with the number of pedestrians on the streets. Overall, the results support the validity of Walk Score in measuring urban design related to walking in Hanoi

7.4.3 Temperature, humidity, air and noise pollution.

In comparison with other urban typologies, the temperature was lower, and humidity was higher on the streetside in New Urban Areas thanks to their urban design characteristics. The well-presented trees along streets there provide shade for pedestrians, and the low built-up density, with many open spaces such as parks, squares and lakes, allows better wind ventilation (see figure. The high number of lakes in those areas also contributes to the high humidity there

The average level of PM2.5 across urban typologies was 63 $\mu g/m^3$, much higher than both the Vietnamese standard ($25\mu g/m^3$) (Ministry of Natural Resources and Environment, 2013) and the WHO guideline limit (10 $\mu g/m^3$) (World Health Organization, 2016). Ancient Quarter and Urbanised Villages Areas had the highest level of air and noise pollution due to the heavy traffic and the high built-up density there. The rapid urbanization with numerous construction activities may also contribute to the high level of PM2.5 in Urbanised Villages Areas. Conversely, thanks to the high proportion of trees and parks and the less heavy traffic, the French Quarter, Collective Housing Quarter and especially New Urban Areas had a lower level of air and noise pollution. The conditions of temperature, humidity, air and noise pollution seemed to have minor impacts on the prevalence of walking. As can be seen from Figure 7- 5, the number of pedestrians is higher in highly polluted urban typologies and very low in New Urban Areas with an acceptable level of pollution, contradicting the normal logic that air and noise pollution discoursing walking. Hanoi citizens are aware of and dissatisfied with the air and noise pollution (Phan et al., 2010; Vuong, Phu, Le, & Van Khuc, 2021), however, after many years of living with them, they tend to get used to and be more tolerant with these conditions in comparison with people from developed countries (Gjestland, Nguyen, & Yano, 2015; Phan et al., 2008).

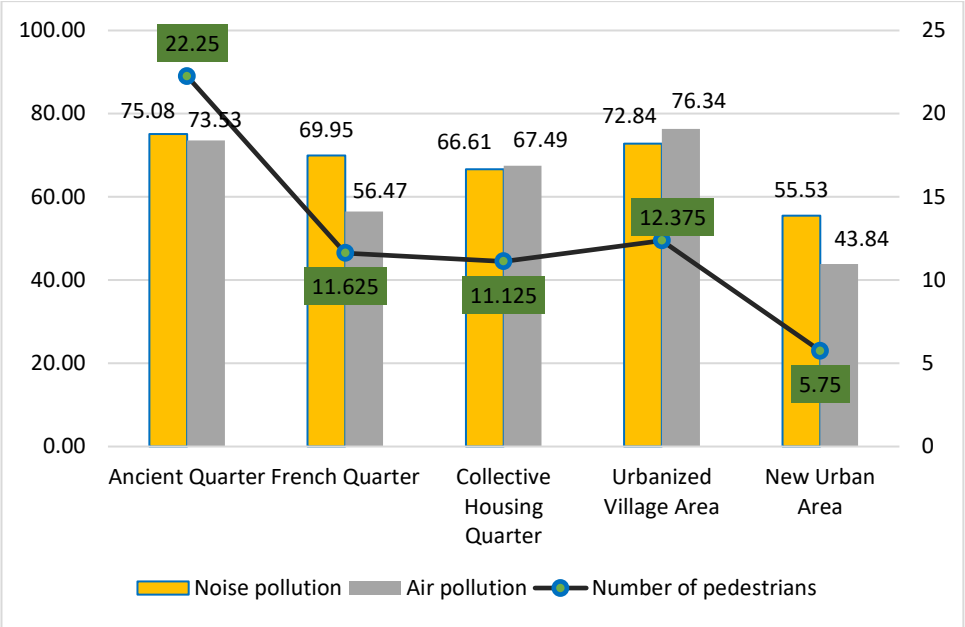

Figure 7-5 Average number of pedestrians, air and noise pollution across five urban typologies.

7.5 Summary

The present study evaluated the urban design qualities across Hanoi and demonstrated that urban design qualities vary across the five urban typologies. *Imageability* and *Complexity* are the two urban design qualities that vary the most, whilst the *Human Scale*, *Enclosure*, and *Transparency* typologies have little variation, except for the case of the *New Urban Area* typology. The combined characteristics of the urban typologies have an impact on the quality of urban design in both a positive and negative direction. Regardless of the locations, streets and areas that have the same urban typology tend to have the same level of urban design quality. Among the five urban typologies, the *Ancient Quarter* has the highest score for urban design qualities as well as the highest number of pedestrians despite being the oldest urban typology. In contrast, although being carefully designed as well as having a better system of infrastructure, the *New Urban Areas* have lower scores across all five urban design qualities. This finding suggests that the path Hanoi is following to develop the city may need to be reconsidered if one is going to prioritise more sustainable urban areas. Rather than adapting modern Western-style planning and urban design, it's essential to study the existing local urban forms and typologies in order to attain and apply the best urban design. It's also important to learn from lessons that have been invoked from experiences of urbanization in Western countries. The research also confirmed the correlation between the number of pedestrians and the urban design qualities score. The streets with better urban design qualities have a

higher number of pedestrians. This finding underlines the role of street-level urban design in promoting the walkability of a place that has been recognized in previous studies.

In terms of methods, the research has successfully tested the urban design qualities measurement tool constructed by Ewing and Clemente (Ewing & Clemente, 2013), which was developed for US cities, which differ enormously from Hanoi where the urban context and urban design are significantly different. The current study has responded to a gap in our knowledge related to street-level urban design, especially among low and middle-income countries of Asia. The findings of the study were also compared with previously studied cities, highlighting significant differences between Asian and Western urban design qualities. Future validation studies of the measuring tool developed for this research should be conducted in other cities from various parts of the world to better understand the urban design qualities in different cultures and urban contexts. However, adjustments and the addition of new criteria are essential to capture the influences of different cultures and the urban context of the related urban design qualities. For example, when applying measurement tools to high-density urban contexts such as Asian cities, the measures of Imageability and Complexity of the tool which relies on the number of buildings and the number of people on street, need to be adjusted. Also, new criteria should be added to assess the informal and temporary elements that are commonly presented on urban streets of developing countries such as food stalls, street markets or "semi-public semi-private" spaces and street furniture (To, 2011), which may have a considerable impact on the sense of complexity, imageability and human scale.

In addition, the study applied the Walk Score to Hanoi and found that the Walk Score was correlated with urban design qualities as well as the number of pedestrians on the streets, indicating the reliability of the tool in the context of Hanoi. The study also examined the temperature, humidity, air and noise pollution across Hanoi and found these attributes varied greatly between the five urban typologies with the New Urban Areas having the most ideal conditions. However, those environmental factors seemed not to affect the walking behaviours as expected.

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CHAPTER 8 SUMMARY OF FINDINGS AND RECOMMENDATIONS

8.1 Introduction

Although research on the relationship between walking and urban design has gained popularity in recent years, there is a paucity of such research in low and middle-income countries, especially in Asia, where cities have high population densities along with a vibrant mix of uses (Chen, Chiu, & Lin, 2020). Most cities in low and middle-income countries in Asia like Hanoi, are in the middle of rapid urban development with enormous demand for urban transportation, offering valuable opportunities to integrate urban design interventions that support active transport like walking. Therefore, research to fully understand the impact of urban design on walking is essential to developing sustainable urban development policies and strategies. The research presented in this thesis highlights the prevalence of walking and its relationship to urban design across Hanoi. This chapter summarises the significant findings and limitations of the research, along with making recommendations and directions for further research.

8.2 Summary of the findings

8.2.1 Findings on the prevalence and characteristics of walking

Despite many challenges, walking was still a very popular mode of transport in Hanoi, particularly for short-distance trips and recreational activities. The results highlighted that walking accounted for 58% of the total number of trips and 35% of total travel time. On average, a person took about 3 to 4 walking trips per day which equated to 30 minutes of walking per day. This amount of walking meets the recommended amount of physical activity advocated by most countries and the WHO (Piercy et al., 2018; WHO, 2020). The prevalence of walking was found to be associated with several demographic characteristics namely, age, gender, body mass index, marital status, education level, and employment status. For example, age was positively correlated with the amount of walking time, suggesting that older people walked more than younger residents. Participants with higher BMI were less likely to engage in walking, but when they did walk, they had significantly longer trips than those with lower BMI. Household characteristics were also found to influence walking frequency. Participants in a household with more household members or who had children walked more than those in

a smaller household with no children. Participants who owned cars or motorcycles also walked less than those who did not have access to motorised vehicles.

The findings on the purpose of walking trips highlighted that walking for transport accounted for the majority of trips compared to walking for recreation. Besides home-based purposes, walking to 'Eat a meal' and or 'Shopping' were the primary purposes for participants to undertake walking trips. Walking to 'Change travel mode' was also common among the purposes, highlighting the important role of walking in chained trips or multi-modal trips in Hanoi. The average duration and distance of a walking trip were 7.3 minutes and 433 meters, respectively. Walking to school was the longest walking trip cited, suggesting the density of educational land use was lower than other services. The duration of the walking trips recalled by the participants was significantly longer than the calculated duration using Google Maps API. Participants might choose different routes instead of the shortest route on Google Maps or they walked at a slower speed than the standard speed of Google Maps due to various reasons such as walking in groups or having to avoid obstructions on the sidewalk. In terms of destinations for walking, restaurants and coffee shops were some of the most popular destinations reported by participants, reflecting the vibrant streets in Hanoi. Both formal and sidewalk restaurants and cafes are present on every corner of the city and become an important local culture (Geertman, 2010). Although only accounting for a small proportion (1%) of common destinations, the presence of spiritual places as walking destinations shows an important factor in the culture of the city which is religion. Hanoi has a diverse and dense system of spiritual places including pagodas, temples, shrines, churches, and communal houses (Thi Nhu, 2017). The study also found a high prevalence of accompanied walking trips (almost 56% of total walking trips). In terms of accompanied trips, participants walked with their family members, friends, lovers, or neighbours - as in the case of older people. However, participants tended to spend more time when they walked alone compared with when they walked with others, which can be explained by the fact that people walking alone can have more freedom to decide their speed without worrying to adjust their speed to match others as in walking in a group. Another finding was that the majority of the recalled walking trips were recurring trips (60%), especially in the case of commuting trips to work or school since those type of trips often requires a fixed schedule. Participants reported various reasons for choosing a walking route. Common reasons are due to reduced time or reasons of efficiency (shortest route), safety reasons (route offers most security, the route has least number of streets to cross or reduced traffic), design reasons (route has

good walking facilities), experience reasons (the route is beautiful or interesting, the route has many restaurants, cafés, activities). Participants also reported barriers that discourage them from walking and facilitators that encourage them to walk. Common barriers included: 'too lazy to walk', 'do not have time to walk', 'too tired to walk', 'have bad mood', whereas common facilitators were 'have free time', 'believe that walking is good for their health' and 'have people to walk with'.

The analysis highlighted the relationship between walking and demographic factors as well as the urban typologies the participants lived in. Participants with higher BMI were less likely to walk whilst unemployed people were more likely to walk than those who were employed. Age was found to be positively associated with walking time, meaning older people walked more than younger ones. In addition, people who were single or divorced/widowed/separated walked more than those who were married. These results suggest that participants who had more free time and less responsibility (being retired, unemployed, single, divorced, widowed) tended to walk more. In terms of urban typologies, participants in New Urban Areas were less likely to walk and if they walked, they had fewer walking trips than those in other urban typologies. However, they had significantly more walking time than participants in the Collective Housing Quarters and the French Quarter. They also had the largest average walking time per trip of all urban typologies. These findings suggest that conditions in the New Urban Areas often discourage people from walking but if they walk, they must walk longer trips than participants in other typologies, consequently, leading to a more total amount of walking time given that number of trips is similar. The urban form in the New Urban Area is characterised by a low-density built environment and low mixed land use, requiring residents to walk longer to reach their desired utilitarian destinations.

8.2.2 Perceived urban design and walking.

The variation of perceived urban design across the five urban typologies and the relationship between the perceived urban design and walking in Hanoi was examined Based on the Neighbourhood Environment Walkability Scale (NEWS) (Saelens, Sallis, Black, & Chen, 2003) and its abbreviated version (NEWS-A) (Cerin, Saelens, Sallis, & Frank, 2006), A newly developed and validated Vietnamese version (NEW-S-V) was trialled. The NEW-S-V had a high score of intraclass correlation coefficient, confirming the reliability of the NEW-S-V. The test-retest reliability scores of NEW-S-V were also comparable to other adapted versions of NEWS from other Asian countries.

The results from the survey using NEW-S-V highlighted that Hanoi has a high score in Residential Density, Land Use Mix and Crime Safety. Although Hanoi does not have many high-rise residential apartments, the built density is extremely high in most parts of the city with the dominance of "tube houses" with very few open spaces. Most destinations and services in Hanoi such as restaurants, coffee shops or markets were perceived to be within a distance of a 20-minute walk, except for workplaces, indicating that most participants did not work near their homes. Participants believed that Crime Safety was not a barrier to walking in Hanoi and that walking was generally safe throughout Hanoi; day or night. In contrast, the participants shared their concerns about Traffic Safety in Hanoi. Walking Facilities in Hanoi were also perceived negatively, except for the New Urban Areas, due to the poorly maintained sidewalks as well as the encroachment of sidewalks for business, parking, and personal activities.

The perceived urban design also varied across the urban typologies. Compared to other urban typologies, the New Urban Areas had significantly higher perceived scores for Residential Density, Walking Facilities and Street Connectivity thanks to the popularity of high-rise apartments, high-quality walking infrastructure and well-designed street networks. Conversely, the New Urban Areas had limited services and low-mixed land use due to the dominance of residential buildings, leading to the low scores of perceived Land use mix and Access to services.

Results from the statistical analysis suggested that Land use mix was positively associated while Street Connectivity was negatively associated with the likelihood of engaging in walking. Also, Access to services was positively correlated while Walking Facilities negatively correlated with the number of walking trips. These findings highlight the role of mixed land use in promoting walking. Highly connected streets and high-quality walking infrastructure may not be enough to encourage people to walk more if their neighbourhoods have poorly mixed land-use with limited services and destinations.

In summary, the research illustrated the perceived urban design in Hanoi and compared those urban design factors among five urban typologies across the city. The likelihood of walking and the number of walking trips were found to be correlated with various factors of perceived urban design in different directions. The research also validated and confirm the reliability of the NEWS tool in measuring the perception of urban design in the context of Hanoi.

8.2.3 Urban design qualities and walking.

The urban design qualities of Hanoi's streets (using the tool developed by (Ewing, Handy, Brownson, Clemente, & Winston, 2006) were compared across the five urban typologies of the city.

In general, the streets in Hanoi have high scores in relation to the design qualities of Imageability, and Complexity; thanks to a large number of buildings, the ubiquitous presence of outdoor dining, the diverse colours of the facades, and the crowded streets. On the other hand, the dense and compact urban forms in most parts of the city enhance the qualities of Enclosure and Human Scale. Although the height of buildings is restricted in the most inner part of the city, the popularity of narrow streets helps to balance the" room-like" feeling that contributes to the Enclosure quality. Although Hanoi doesn't have a regulation for street-level windows like other cities, the dominance of shophouses (Davis, 2012) and the very high level of commercial activities across the city, means there is a high proportion of windows at the street level (61%) which increases the Transparency design quality. A noticeable negative factor for urban design quality is the absence of public art in all studied areas, which might be due to inadequate arts infrastructure, the lack of funding and resources, and stringent government censorship (Brittney, 2013).

Comparison between urban typologies demonstrated that urban design qualities vary significantly across Hanoi. Imageability and Complexity are the two urban design qualities that vary the most, whilst the Human Scale, Enclosure, and Transparency typologies have little variation, except for the case of the New Urban Area. The urban typologies together with their characteristics have an impact on the quality of urban design in both a positive and negative direction. For example, the Imageability of the Ancient Quarter is boosted by the distinct architecture comprising a mix of ancient houses with modern residential and commercial buildings, while the identical rectangular shape of the Soviet-style apartment blocks, the dominant architecture typology in Collective Housing Quarters denoted the Imageability quality in those areas. Another example is that the high solid walls or fences around large government buildings and private residential villas in the French Quarter and the New Urban Areas may contribute to increasing the Enclosure quality but, at the same time, reduce the Transparency quality significantly. Among the five urban typologies, the Ancient Quarter has the highest score for urban design qualities as well as the highest number of pedestrians despite being the oldest urban typology. In contrast, although being carefully designed as well as having a better system of

infrastructure, the New Urban Areas have lower scores across all five urban design qualities. This finding suggests that Hanoi should reconsider the path for developing the city. Rather than adapting modern Western-style planning and urban design, it is essential to study carefully all the existing local urban forms and typologies to attain and apply the best urban design. Learning the successes and failures from the experiences of urbanization in Western countries is also important.

The research compared urban design qualities in Hanoi with the other three cities from studies that used the same measure. Hanoi and Gurgaon, two cities in low- and middle-income countries in Asia, share similar urban design qualities, while New York and Brisbane, two cities from high-income countries which follow the typical Western-style urban planning, have similar scores of urban design qualities. Thanks to the high number of pedestrian movements and activities on the street, the Imageability and Complexity scores of Gurgaon and Hanoi are significantly higher than those of New York and Brisbane. The findings reflect the differences in urban design qualities between cities in low- and high-income countries as well as between Asian cities and Western cities.

The Walk Score, a popular walkability index (walkscore.com), was calculated for the observed streets and found to be significantly correlated with multiple urban design qualities including Complexity, Imageability and Transparency. This result can be explained by the fact that both Walk Score, Complexity and Imageability qualities are calculated by the number of destinations in the areas. Although Transparency is not a destination-based measure, streets with a lot of destinations often have transparent façades, thereby having high scores of Transparency quality.

The research also found a correlation between the number of pedestrians and the attained score for urban design qualities. The streets with better urban design qualities have a higher number of pedestrians. This finding confirmed the role of street-level urban design in promoting the walkability of a place which has been recognized in other studies(Ewing & Clemente, 2013; Parashar & Bnayan, 2020; Yin, 2017).

8.2.4 The environmental factors and walking.

Environmental factors such as temperature, humidity, air and noise pollution were measured using various types of sensors and meters. Thanks to the presence of trees along many streets and the high number of open spaces like parks, squares and lakes, the temperature was lower, and humidity higher on the streetside in New Urban Areas compared to other urban typologies. The average level of air pollution in Hanoi,

measured through the level of $PM_{2.5}$, was 63 μg/m^3, which was higher than both the Vietnamese standard (25μg/m^3) (Ministry of Natural Resources and Environment, 2013) and the WHO guideline (10 μg/m^3) (World Health Organization, 2016). The average level of noise pollution in Hanoi, measured through the level of LAeq, was 68 dB, which can lead to mental and bodily fatigue if exposed for a long period of time. Due to the heavy traffic, the Ancient Quarter and Urbanised Villages Areas had the highest levels of air and noise pollution at the streetside. Conversely, the French Quarter, Collective Housing Quarter and especially New Urban Areas had a lower level of air and noise pollution thanks to the less heavy traffic, the high proportion of streets having trees on sidewalks, and the high number of parks and open spaces. Results of the analysis showed that environmental factors such as temperature, humidity, air and noise pollution seemed not to significantly influence the prevalence of walking. For example, despite having a high level of air and noise pollution, Ancient Quarter still had a higher number of pedestrians than New Urban Areas where the level of pollution was lower. However, in comparison to other urban typologies, participants in the New Urban Areas had the longest average walking time per trip, facilitated by the low level of air and noise pollution and the comfortable temperature there.

8.3 Limitations

This research has several limitations. In general, the thesis only covered the walking activities that happen in the outdoor environment. Walking in an indoor environment such as inside a shopping mall, a supermarket or a museum can contribute significantly to the health of walkers. The urban design may not directly influence those types of walking, but it can contribute indirectly. For example, the lack of mixed land use in New Urban Areas, presented through few shops, restaurants, and outdoor markets, can limit the people's activities to happen at shopping malls, thereby increasing the indoor walking there. Consequently, those trips in the indoor environment may replace or reduce the amount of walking that happens in the outdoor environment.

The present research acknowledges the limitation of the small sample size, which was due to the constraints in human resources, time, funding, and equipment. In the studies on walking and perceived urban design, the research reported findings from 215 participants. Among them, only 48 participants consented to the test-retest reliability interviews. In the study on urban design qualities, the audit was conducted on only 40 streets across Hanoi. Similarly, in the study on environmental factors (temperature,

humidity, air and noise pollution), sensors and meters were installed and used in only 40 streets mentioned above. Although the sample size was small across the studies, the researcher succeeded in guaranteeing the randomness and the well spatial distributions of the sample by sampling strategies highlighted in Chapter 4. The research also only covered 5 urban typologies in Hanoi. However, these urban typologies are the most typical ones, representing the main events and influences in the history of urban development of the city.

The thesis also acknowledges the limitation in comparing the urban design of Hanoi to other cities through referenced studies. Such comparisons may contain some errors because of the considerable differences in the study objectives, the size of the samples studied and the operationalization of the instruments in the referenced studies. It should be noted that the limited number of relevant studies and geographical locations of the studied cities reduced the ability to robustly compare different urban models and urban contexts.

In addition, the limitations include the uniqueness of Hanoi - a capital city and centre of tourism in Vietnam, which may increase the data variation. For example, the number of pedestrians on streets in tourist areas may contain not only residents but also tourists. Also, the number of destinations in those tourist areas may be higher than in other areas due to various services dedicated to tourism activities.

8.4 Recommendations for future research

From the findings and limitations of this research, the following future research studies are recommended:

- Future research can investigate the walking routes selected by pedestrians to understand better the impacts of urban design on the walking experience during walking trips. The present research was only able to record the origin and destinations of the walking trips, therefore it was unable to explore the routes in between.
- Future research can identify the threshold at which urban design have positive impacts on walking and the tipping point where those impact may change directions. For example, a high density of services and destinations can increase the walking amount in an area. However, if that density is too high to a certain point, it may build up people's low tolerance to walking

long distances because they can have everything they need in a very short radius of their home.

- The present research has highlighted that environmental factors such as air and noise pollution in Hanoi do not have significant impacts on the decision to walk and the amount of walking. However, future research can focus on exploring if this air and noise pollution reduces the benefits of walking. It is also necessary to study the impacts on walking by seasonal weather factors such as cold monsoon winds in winter or heavy downpours in summer that often causes flooded streets.
- The cross-sectional design of the present research could identify associations between urban design and the prevalence of walking. Future longitudinal studies will be useful to see if proactive interventions or passive changes in urban design would lead to changes in the walking behaviour of Hanoi citizens.
- Future research can apply more modern technologies and equipment, if available, to obtain more detailed and accurate data, and the same time, to make larger-scale studies more practical.
- The present research can be applied in other cities in Vietnam. It is essential to see if the findings in Hanoi are comparable to other cities in Vietnam which share similar or different contexts.
- Hanoi shared many similarities with other Asian cities in low-and middle-income countries such as the influences from the feudal and colonial periods on urban development, the rapid urbanisation process, the high density of urban population, inadequate urban infrastructure, the high number of pedestrians on streets, etc. Therefore, the results from Hanoi case study are relevant to other Asian cities. Future research can apply the research framework in Hanoi to other cities in Asia to confirm and explore the relevance between the cities.

8.5 Policy implications

8.5.1 Walking Policies.

Research on city planning policies of 25 cities highlighted that Hanoi has inadequate policies related to promoting walking and delivering pedestrian infrastructure (Lowe et al., 2022). The result of the present research shows that people were concerned about the encroachment of the sidewalk as well as the poorly maintained and low-quality walking infrastructure. Hanoi's authorities have put in some efforts in regaining pedestrian space, such as issuing bans on parking on sidewalks in some streets, banning and penalizing activities that encroach on sidewalks for business activities, or destroying constructions encroaching on sidewalks. However, those measures are often only in form of temporary campaigns or individual programs which often face resistance from the residents and only have a temporary effect. The city should carefully study the current conditions and the needs of citizens and thereby construct the walking policies from the people's point of view. Walking policies should include but are not limited to five objectives below:

- To promote the benefits of walking
- To improve the walking infrastructure.
- To increase the number of walking trips
- To improve the experience of walking
- To improve pedestrian safety

Furthermore, policies that promote walking should also be integrated into policies of relevant fields such as transportation, public health, and urban planning.

8.5.2 Education interventions

To shift community perception and attitudes to favour walking, education interventions are also essential. Comprehensive educational interventions should cover not only the benefits of walking but also conditions in Hanoi that are associated with walking, and the rights and obligations of pedestrians. Safety is another important factor that could be incorporated into the walking education program. Pedestrians need to be educated to be more conspicuous to their own safety and other vehicles when participating in heavy traffic as in Hanoi. The city should organise social marketing and public campaigns to increase public support for walking.

8.5.3 Urban design policies and guidelines that support walking.

As highlighted in this research, urban design policies and guidelines must aim to improve the urban design features that support walking including Residential Density, Land Use Mix, Access to Services, Street Connectivity, Walking Facilities, Aesthetic, Traffic Safety and Crime Safety. Among them, the findings show that Land Use Mix and Access to Services are the most important factors. These two factors have already been presented in most parts of Hanoi, however, were absent in the New Urban Areas, which suggests a focus on these factors in urban design policies and guidelines for new development projects. Besides, street-level urban design qualities such as Imageability, Enclosure, Human Scale, Transparency and Complexity also play an important role in promoting walking. Policies and guidelines to improve those qualities should be implemented. For example, the proportion of windows at street level should be required in new buildings to increase Transparency quality. To increase Complexity quality, the integration of public art in new development projects should be required through a specific proportion of project cost or at least be encouraged through incentive schemes like tax reduction. Buildings should be set back from front or side boundaries, and from other buildings within the site to have more open spaces for pedestrians, which increases the Imageability quality. Streetscape projects should ensure the adequate presence of trees, small plants, street furniture, and street lighting. The city should also encourage and call for projects that convert streets reserved for vehicles into pedestrian-and-bike-friendly boulevards with pocket-sized urban parks and outdoor dining areas.

8.6 Conclusions

In conclusion, the study contributes to the understanding of the prevalence of walking as well as its associations with urban design in Hanoi. The study provides policymakers, planners, urban designers, architects, and others with important information for developing sustainable urban design policies, strategies and interventions that will make the city more walkable and ultimately promote the health of residents.

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APPENDICES

APPENDIX 1 SURVEY QUESTIONS

Note:
This is a copy of the survey exported from Qualtrics. The original survey will be downloaded to the Qualtrics App on tablets. The survey will be undertaken face-to-face with participants using a tablet. The researcher will prompt the questions one by one during the survey by reading the questions and also showing the screen of the tablet to participants. The researcher will be the person who inserts all answers provided by the participants into Qualtrics App except for some questions such as ones that require participants to tap on an interactive map on the screen to select a location.

Some questions can only be displayed correctly on the tablet such as questions that have a time picker, year picker, questions require to drag and drop items or rank a list of choices. The researcher has made some notes to these questions when exporting to this version.

Confirmation page

Thank you for your interest in participating in this research project.
Please confirm the following information:

1. I'm over 18 years old.
2. I'm current residents of this household.
3. I have been residents of this area for at least 6 months.
4. I am able and willing to answer questions in Vietnamese.
5. I am not having any disability that prevented independent walking.
6. I have no signs of cognitive impairment.
7. I have completed the consent form.

- ☐ Yes. I confirm.
- ☐ No. I don't confirm

Explanation part.

[The researcher will read the definitions and explanations of some terminologies used in this survey]
Before we start this part, I'd like to explain some of the terminologies will be used in this survey:

TRIP
A 'trip' is defined as one-way travel from point A to B on public roads. The 'purpose' of a trip depends on point B, the destination. Each trip has one purpose and one type of transportation mode used. For example, a school student travels to school by bus. This is counted as two trips:

Trip 1: Walk from home to the bus stop. The purpose of this trip is 'change mode of travel'. The mode used is 'walking'.
Trip 2: Take the bus from the bus stop to school. Now the purpose has changed to 'education'. The mode used has changed to 'bus'.

A round trip counts as two trips. For example:
1) You drive to the grocery store and back.
2) You go for a half-hour jog or bike ride. (This is counted as two trips because you leave home on the first leg of the trip and return home on the second leg. Your first "destination" is your halfway point and second "destination" is your home).

Sometimes, you may have multiple trips links together (trip chains) and it's difficult to separate each segment of the journey. For example, you went back home from the workplace but visited a chemist on the way to buy some medicine and then visited the supermarket to buy some foods before coming home. In that case, I will ask you for stops you have made between your trip. A stop will act as a destination for the trip prior to it and the origin for the trip after it. A stop will only be counted when you have a purpose for it. In the example above, we can count two stops: one at the chemist and another at the supermarket.

All trips are counted whether you are a passenger, driver or pedestrian.

LOCATION
In questions related to location/place/destination/origin, please choose a location on the display map or list the address, building or nearest place to the location. You do not need to determine the precise address of every location if you can name an place, or a building/store, which is common enough to be recognized (e.g.,"Thong Nhat Park").

TIME
Please try to keep good estimates of the start and arrival times. These are the start and

arrival times of the trip. For example, when we are talking about a trip to a store, please let me know the time you left for the store (trip start time), and then the time you arrived at the store (trip arrival time). The time you left the store will be trip start time for the next trip, and then the time you arrived at your next destination will be trip arrival time for this trip. The time you leave the store is not the trip arrival time of the first trip; we are only interested in the duration of the actual trip to the store, not how much time was spent at the store.

TRAVEL MODE

You can choose the travel mode from the list below:
Car or truck (driver)
Car or truck (passenger)
Motorcycle (driver)
Motorcycle (passenger)
Bicycle (driver)
Bicycle (passenger)
Bus/transit (list the route number if possible)
School bus
Taxi/rideshare service (passenger)
Walk
Other
Be careful if you select "car or light truck", "motorcycle" and "bicycle" because there are two answers for these categories - passenger or driver.

PURPOSE

Trip purposes are divided into these categories:

Go Home: *A trip from some other location to your usual place of residence.*

Personal Business: *Travel which is made to obtain services, not products.*

Shopping: *Travel to shop or to purchase products.*

School: *Travel by a student to college or school. Travel by a teacher or other employee to the school where employed should be classified as a work commute trip. If you are driving a student to school, the trip should be classified as "drive a passenger."*

Work Commute: *Travel to or from your workplace.*

Other Work/business: *Travel done for work, to someplace other than the workplace.*

Go to sports/recreation place: *Travel to sports/recreation place*

Recreation: *Trips made for recreation*

Sport/Exercise: *Trips made for sports or exercises*

Eat a Meal: *Examples include going to a restaurant, going to a friend's house for dinner, or home from work for lunch. Stops for snacks or refreshments should be classified as "social/recreation".*

Accompany or transport someone: *Use this category for trips or stops to pick up or deliver someone to a specific location.*

Change Travel Mode: *If you drive your car, walk, or ride your bike to catch the bus, this is a "change travel mode" trip.*

Other: *Any trip you make which does not seem to fit in the categories listed should be put in the "other" category. Please list the detailed purpose in the blank provided. If you can't decide between two categories, also list it in the blank provided.*

NEIGHBOURHOOD

Residential neighbourhoods were defined as 1000-meter buffers around the centroid of each participant's home.

Do you have any questions or anything you are not clear about these terminologies?

- ○ *No (1)*
- ○ *Yes (2)* _____

SURVEY

PART A - TRAVEL DIARY

[*In this part, I will ask you questions about your travel activities in 24 hours prior to this moment.*
This part will consist of two sections: Section I - All trips and Section II - Walking trips]

Section I – All trips
[*We will begin with section I - All trips.*

In this section, we will recall all the trips you have made in 24 hours prior to this moment]

T1. First of all, about this time yesterday, have you undertaken any trip?

- ○ Yes (1) [continue next questions]
- ○ No. E.g. I stayed at home all day (2) [automatically skip to part 3 of the survey]

T2. Let's talk about your first trip, what was the main purpose of this trip?
(E.g. select Eat a Meal if you went for breakfast.)

- ☐ Go Home (1)
- ☐ Personal Business (2)
- ☐ Shopping (3)
- ☐ School (4)
- ☐ Work Commute (5)
- ☐ Other Work/business (6)
- ☐ Recreation (7)
- ☐ Eat a Meal (8)
- ☐ Drive (Drop) a Passenger (9)
- ☐ Sport/Exercise (10)
- ☐ Go to Sports/Recreation place (11)
- ☐ Pick Up a Passenger (12)
- ☐ Change Travel Mode (13)

☐ Other: (14) _____

T3 Where did you start this trip? ((E.g. home, hotel, workplaces)

_____

T4 When did you start?

[There is a time picker for this question on tablet]

T5 What was the destination for this trip?

_____

T6 Before reaching [automatically insert text entry value from question T5 here] did you make any stop? (E.g. stop at a shop to buy something)

- ○ Yes (1) [automatically skip to block of questions for trip chain]
- ○ No (2) [automatically skip to questions]

This is the block of questions for trip chain which will appear if yes is selected in question T6

TS1.1 Why did you stop?

- ○ Personal Business (1)
- ○ Shopping (2)
- ○ Drop or Pick Up Someone (3)
- ○ Change Travel Mode (4)
- ○ Other: (5) _____

TS1.2 Where did you stop? (E.g. a chemist, a grocery store)

_____

TS1.3 When did you stop?

[There is a time picker for this question on tablet]

TS1.4
What mode of transport did you use for this trip (from [automatically insert text entry value from question T5 here] to [automatically insert text entry value from question TS1.2 here]

- ○ Car (driver) (1)
- ○ Car (passenger) (2)
- ○ Motorcycle (driver) (3)
- ○ Motorcycle (passenger) (4)
- ○ Bicycle (driver) (5)
- ○ Bicycle (passenger) (6)
- ○ Bus/transit (list the route number if possible) (7)
- ○ School bus (8)
- ○ Truck/ Comercial Vehicles (9)
- ○ Taxi/rideshare service (passenger) (10)
- ○ Walk (11)
- ○ Other (12) _____

TS1.5 When did you leave that stop?
[There is a time picker for this question on tablet]

TS1.6 After leaving this stop and before reaching [automatically insert text entry value from question TS1.2 here] did you make any other stop?

- ○ Yes (1) [Block of questions from TS1.1 to TS1.6 will be repeated until the answer in TS1.6 is no]
- ○ No (2) [Skip to T7]

T7 What mode of transport did you use to reach [automatically insert text entry value from question T5 here] ?

- ○ Car (driver) (1)
- ○ Car (passenger) (2)
- ○ Motorcycle (driver) (3)
- ○ Motorcycle (passenger) (4)
- ○ Bicycle (driver) (5)
- ○ Bicycle (passenger) (6)
- ○ Bus/transit (list the route number if possible) (7)

_____

- ○ School bus (8)
- ○ Truck/ Comercial Vehicles (9)
- ○ Taxi/rideshare service (passenger) (10)
- ○ Walk (11)
- ○ Other (12) _____

T8. When did you arrive [automatically insert text entry value from question T5 here]?

[There is a time picker for this question on tablet]

T9 Did you head to any other place after that?

- ○ Yes (1) [Questions from T2 to T9 (including block of questions for trip chain if needed) will be repeated until the answer in T9 is no]
- ○ No (2)

Section II Walking trips

[Now we will move to section II of Part A: Walking trips.
In this section, we will focus on all walking trips you have listed in previous section]

WL Based on your previous answers, below is the list of walking trips you have made in 24 hours prior to this moment. Please read again and confirm those trips.

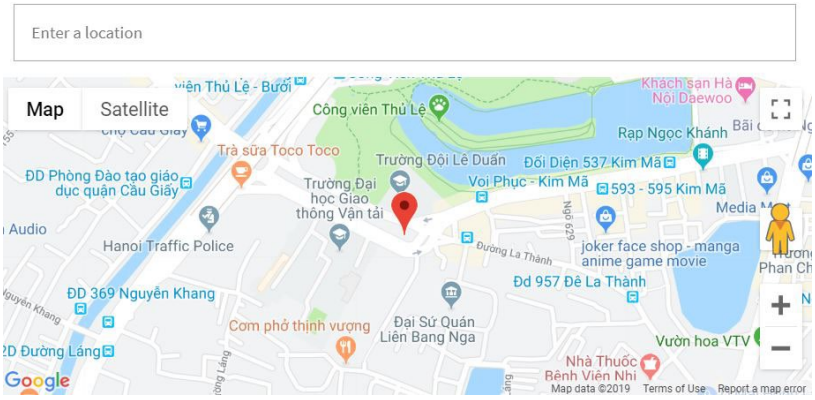
[For this question, inserted text entry value and selected value from the previous questions in the trips which have walking as mode of transport will be piped here to establish a list of walking trip. If no walking trip has been recalled, skip to Part B of the survey]

☐ A walking trip with the purpose of [value to be inserted automatically]. This walking trip started at started at [value to be inserted automatically] and finished at [value to be inserted automatically] (1)

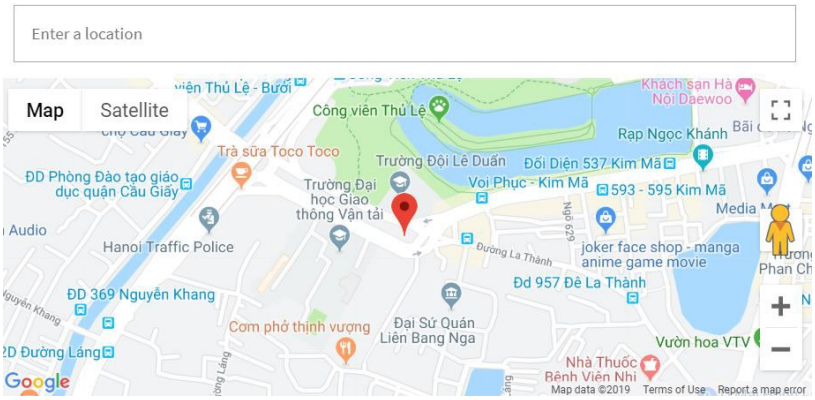
☐ A walking trip as a part of the multimodal trip with the purpose of [value to be inserted automatically]. This walking trip started at [value to be inserted automatically] and finished at [value to be inserted automatically] (2)

☐ A walking trip as a part of the multimodal trip with the purpose of [value to be inserted automatically]. This walking trip started at [value to be inserted automatically] and finished at [value to be inserted automatically] (3)

W1 Let's start with the first walking trip you listed above. Where did this trip start? Please identify this place on the map or insert the address if known. Alternatively, you can name a building/store, or a place which is common enough to be recognized



W2 Where did this trip finish? Please identify this place on the map or insert the address if known. Alternatively, you can name a building/store, or a place which is common enough to be recognized



W3 For this trip, who did you walk with?

- ○ I walked alone (1) [Skip question W4]
- ○ I walked with another person (2)
- ○ I walked with more than one person. (3)

W4 What is the relationship between you and the person/people you walked with?

- ○ Family members/Relatives (1)
- ○ Partner/Lovers (2)
- ○ Friends/School mates (3)
- ○ Colleagues (4)
- ○ Mixed relationship (5)
- ○ Other (6) _____

W5 Which statement below would best describe your decision to choose the route for this trip? (You can choose more than one answer).
[This question can only be displayed correctly on the tablet such as it requires to drag and drop items in three windows main reason, secondary reason and third reason]

Main reason	Secondary reason	Third reason
_____ No reason (Selected randomly or being guided/directed by others) (1)	_____ No reason (Selected randomly or being guided/directed by others) (1)	_____ No reason (Selected randomly or being guided/directed by others) (1)
_____ It is the only route available (2)	_____ It is the only route available (2)	_____ It is the only route available (2)
_____ It is the quickest route (3)	_____ It is the quickest route (3)	_____ It is the quickest route (3)
_____ I always go that route (4)	_____ I always go that route (4)	_____ I always go that route (4)
_____ It is the only route I know (5)	_____ It is the only route I know (5)	_____ It is the only route I know (5)
_____ I want to avoid something or someone / being seen (6)	_____ I want to avoid something or someone / being seen (6)	_____ I want to avoid something or someone / being seen (6)
_____ It is the least crowded (7)	_____ It is the least crowded (7)	_____ It is the least crowded (7)
_____ It has more shops, stores, restaurant, etc. (8)	_____ It has more shops, stores, restaurant, etc. (8)	_____ It has more shops, stores, restaurant, etc. (8)
_____ It is beautiful/romantic/interesting. (9)	_____ It is beautiful/romantic/interesting. (9)	_____ It is beautiful/romantic/interesting. (9)
_____ It has least noise/air pollution (10)	_____ It has least noise/air pollution (10)	_____ It has least noise/air pollution (10)
_____ It offers most personal security (11)	_____ It offers most personal security (11)	_____ It offers most personal security (11)
_____ It has the least number of street to cross (12)	_____ It has the least number of street to cross (12)	_____ It has the least number of street to cross (12)

_____ It has good sidewalk/footpath, walking infrastructure and equipment (walking signs, walking traffic lights, zebra crossing, bumper crossing, etc.) (13)	_____ It has good sidewalk/footpath, walking infrastructure and equipment (walking signs, walking traffic lights, zebra crossing, bumper crossing, etc.) (13)	_____ It has good sidewalk/footpath, walking infrastructure and equipment (walking signs, walking traffic lights, zebra crossing, bumper crossing, etc.) (13)

W6 Do you have any other reason that different from he reasons listed above?

_____

W7 Do you take this trip often?

- ○ No (1)
- ○ Yes. Please estimate the frequency: (times per day/week/month) (2)

_____

[Repeat questions from W1.1 to W1.7 for every trips listed in WL]

PART B - PERCEPTION OF WALKING ENVIRONMENT.

[In this part, I would like to ask more information about the way that you perceive or think about your neighborhood]

[Please select the answer that best applies to you and your neighbourhood]

PA1 How common are detached single-family residences in your neighbourhood?

- ○ None (1)
- ○ A few (2)
- ○ Some (3)
- ○ Most (4)
- ○ All (5)

PA2 How common are townhouses or row houses of 1-5 stories in your immediate neighbourhood?

- ○ None (1)
- ○ A few (2)
- ○ Some (3)
- ○ Most (4)
- ○ All (5)

PA3 How common are apartments or condos 1-5 stories in your immediate neighbourhood?

- None (1)
- A few (2)
- Some (3)
- Most (4)
- All (5)

PA4 How common are apartments or condos 6-12 stories in your immediate neighbourhood?

- None (1)
- A few (2)
- Some (3)
- Most (4)
- All (5)

PA5 How common are apartments or condos more than 13 stories in your immediate neighbourhood?

- None (1)
- A few (2)
- Some (3)
- Most (4)
- All (5)

PB1 How long would it take to get from your home to the nearest businesses or facilities listed below if you walked to them? Please select only one option for each business or facility

	1-5 min (1)	6-10 min (2)	11-20 min (3)	20-30 min (4)	30+ min (5)	Don't know (6)
Convenience/small grocery store (1)	○	○	○	○	○	○
Supermarket/big market (2)	○	○	○	○	○	○
Hardware store (3)	○	○	○	○	○	○
Small market/ vegetable market (4)	○	○	○	○	○	○
Laundry/dry cleaners (5)	○	○	○	○	○	○
Clothing store (6)	○	○	○	○	○	○
Post office (7)	○	○	○	○	○	○
Library (8)	○	○	○	○	○	○
Elementary school (9)	○	○	○	○	○	○
Other schools (10)	○	○	○	○	○	○
Book store (11)	○	○	○	○	○	○
Fast food restaurant (12)	○	○	○	○	○	○
Coffee place (13)	○	○	○	○	○	○
Bank (14)	○	○	○	○	○	○
Non-fast food restaurant (15)	○	○	○	○	○	○

Entertainment store (CD, PC games, Internet) (17)	○	○	○	○	○	○
Pharmacy (16)	○	○	○	○	○	○
Your job or school (18)	○	○	○	○	○	○
Bus stop (19)	○	○	○	○	○	○
Park (20)	○	○	○	○	○	○
Sport center (21)	○	○	○	○	○	○
Gym or fitness facility (22)	○	○	○	○	○	○
Community center (23)	○	○	○	○	○	○

PC1 I can do most of my shopping at local stores.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PC2 Stores are within easy walking distance of my home.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PC3 There are many places to go within easy walking distance of my home.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PC4 It is easy to walk to a bus stop from my home.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PD1 The distance between intersections in my neighborhood is usually short (100 meters or less)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PD2 There are many alternative routes for getting from place to place in my neighbourhood. (I don't have to go the same way every time.)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE1 There are sidewalks on most of the streets in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE2
The sidewalks in my neighbourhood are well maintained (paved, even, and not a lot of cracks).

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE3 There is a painted line that separates the sidewalks from parking spaces in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE4 My neighbourhood streets are well lit at night.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE5 Walkers on the streets in my neighbourhood can be easily seen by people in their homes.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PE6 There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF1 There are trees along the streets in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF2 Trees give shade for the sidewalks in my neighbourhood

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF3 There are many interesting things to look at while walking in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF4 There are many attractive natural sights in my neighbourhood (such as landscaping, views).

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF5 There are attractive buildings/homes in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PF6 There are interesting activities to join while walking in my neighbourhood. (street performance, street food, street coffee)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG1 There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG2 There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG3 The speed of traffic on most nearby streets is usually slow (40 km/h or less).

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG4 Most drivers exceed the posted speed limits while driving in my neighbourhood

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG5 The level of air pollution on streets in my neighborhood is often high (e.g. exhaust fumes, dirt)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG6 The level of noise pollution on streets in my neighborhood is often high (e.g. horn, sound of vehicle engine)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PG7 The streets of my neighborhood are often flooded if there is heavy rain.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PH1 There is a high crime rate in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PH2 The crime rate in my neighbourhood makes it unsafe to go on walks during the day.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PH3 The crime rate in my neighbourhood makes it unsafe to go on walks at night.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PH4 My neighbourhood is safe enough so that I would let a 10-year-old boy walk around alone in the daytime

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PI1 Parking is difficult in local shopping areas.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ1 There are major barriers to walking in my neighborhood that make it hard to get from
place to place (for example, railway lines, rivers)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ2 There are physical barriers to walking in my neighbourhood that make it difficult to walk on the sidewalk (for example, utility poles and cabinets, under construction sites)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ3 The streets in my neighborhood do not have many dead-end streets.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ4 Sidewalks in my neighborhood are often occupied illegally that make it difficult to walk (for example, occupied by street vendors, street food shops, shops that facing street)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ5 There are many motor vehicles parked on the sidewalks making it difficult to walk

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ6 There are much litter on the sidewalks making it difficult to walk (including illegal dumped contruction materials, rubbish, old furniture)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ7 There are many homeless people, drug addicts, prostitutes making it unpleasant to walk.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PJ8 Hard weather condition making it unpleasant to walk.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PL1 There are often many walkers on street during the day.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PL2 I often see and speak to other people or my neighbours when I am walking in my neighbourhood.

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PL3 It's easy to ask for help on street (for example, to get directions)

- ○ strongly disagree (1)
- ○ somewhat disagree (2)
- ○ somewhat agree (3)
- ○ strongly agree (4)

PART C – DEMOGRAPHIC INFORMATION

[Now we come to the final part: Part C Demographic information
In this part, I will ask some questions about you]

D1 What year were you born?
[There is a year picker for this question on tablet]

D2 What is your gender?

- ○ Male (1)
- ○ Female (2)

D3 What is your current marital status?

- ○ Rather not say (1)
- ○ Divorced (2)
- ○ Living with another (3)
- ○ Married (4)
- ○ Separated (5)
- ○ Single (6)
- ○ Widowed (7)

D4 How many people live in your household?

- ○ 1 (2)
- ○ 2 (3)
- ○ 3 (4)
- ○ 4 or more (5)

D5 How many children under 16 years old live in your household?

- ○ None (1)
- ○ 1 (2)
- ○ 2 (3)
- ○ 3 (4)
- ○ 4 or more (5)

D6 Please indicate the highest level of education completed.

- ○ Primary School (1)
- ○ High School or equivalent (2)
- ○ Vocational/Technical School (3)
- ○ Some College (4)
- ○ College Graduate (5)
- ○ Master's Degree (MS) (6)
- ○ Doctoral Degree (PhD) (7)
- ○ Professional Degree (MD, JD, etc.) (8)
- ○ Other (9)

D7 Please indicate your occupation:

- ○ Management, professional, and related (1)
- ○ Service (2)
- ○ Sales and office (3)
- ○ Farming, fishing, and forestry (4)
- ○ Construction, extraction, and maintenance (5)
- ○ Production, transportation, and material moving (6)
- ○ Government (7)
- ○ Retired (8)
- ○ Self-employed (11)
- ○ Unemployed (9)
- ○ Student (12)
- ○ Other (10)

D8 Please insert your height and weight in cm and kg.

Height:

_____

Weight:

_____

D9 Do you own motorised vehicles

- ○ Yes
- ○ No

CONCLUSION.

Do you wish to participate in a retest interview? If yes, please insert your availability after 10 days from today.

_____

Do you wish to receive updates and results of this project. If so, please insert your email address below

_____

Thank you very much for participating in this survey.

APPENDIX 2 PUBLISHED ARTICLE

urban science

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Article

Evaluation of Urban Design Qualities across Five Urban Typologies in Hanoi

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Abstract: Urban design has been shown to play a vital role in promoting the health and wellbeing of urban citizens. However, studies of microscale urban design are underrepresented in comparison with macroscale urban design, especially from low- and middle-income countries in Asia, where urban forms are traditionally compact, complex and with multiple layers and varied urban typologies. The study evaluated microscale urban design qualities of streets (n = 40) across five urban typologies in Hanoi—a typical city in a low- and middle-income country in Asia. The study found that urban typologies and their characteristics have particular impacts on urban design qualities. Old and high-density urban typologies tend to report higher urban design qualities than modern and low-density typologies. Urban design qualities are also significantly associated with the number of pedestrians on the streets. Compared to Western cities, the urban design qualities in Hanoi are substantially different, especially in terms of imageability and complexity, reflecting the differences in urban design and cultural context between cities from various regions. Overall, the study contributes to our understanding of urban design circumstances in Hanoi, providing policymakers, planners, urban designers and architects with important insights for sustainable urban design policies, strategies and interventions.

Keywords: urban design; urban design quality; urban typology; microscale; Hanoi

check for updates

Citation: Ho, T.P.; Stevenson, M.; Thompson, J.; Nguyen, T.Q. Evaluation of Urban Design Qualities across Five Urban Typologies in Hanoi. *Urban Sci.* **2021**, *5*, 76. https://doi.org/10.3390/urbansci5040076

Academic Editor: Neil Sipe

Received: 14 August 2021
Accepted: 26 September 2021
Published: 1 October 2021

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1. Introduction

More than half of the world's rapidly growing population now live in cities; this is expected to rise to 68% by 2050 [1]. Cities will need to not only accommodate these growing populations but also respond to several challenges including delivering a built environment that is sustainable, safe and conducive to population health. Given the urgency to deliver cities that have prioritized population health, there is a growing body of literature discussing the urban built environment and factors related to the health and wellbeing of its citizens [2]. An important finding, however, is the variation in the factors reported to be important contributors in the built environment along with how the various factors have been measured, with the latter depending primarily on the spatial scale used in the study [2].

In the macroscale, the most well-known built environment variables are the 3Ds (density, diversity and design) first used by Cervero and Kockelman [3], which were expanded to 5Ds by including destination accessibility and distance to transit [4]. Methods in

macroscale studies are often objective ones that involve collecting and analyzing data from accessible sources such as GIS. Due to the objectiveness and the availability of data sources, the macroscale studies together with the well-known D variables are dominant in the literature of the study of urban environments. Despite their usefulness and popularity, the D variables are argued to be insufficient to represent the success of the urban environment in terms of physical activity friendliness [5]. One of the reasons for this is the challenge in operationalizing the D variables. While the measurement of density and diversity is often straightforward, quantifying the remaining D variable, design, is a challenge [6]. The gross characteristics of street networks such as intersection density and block size, which are mostly used to calculate the design variable, may not affect the experience of people using the street as much as the microfeatures of the streets [6]. The macro variables should be supplemented by subtle qualities of the street environment for a better understanding of the impact of urban design.

Conversely, microscale studies of the urban environment often investigate the physical features and urban design qualities at the street level. Classic urban design literature has presented many theories and concepts related to street-level urban design such as "imageability" by Lynch [7], "eyes on the street" by Jacobs [8], "livable streets" by Appleyard [9] or "soft edges" by Gehl [10]. The classic literature defined and emphasized the importance of microscale urban design; however, few studies have reported empirical evidence and systematic measuring instruments to support and validate their theories. Recent studies on microscale urban design have focused more on developing measurement tools. Perceived and objective are two types of measures often used in urban design measurement tools. Objective measures, such as Microscale Audits of Pedestrian Streetscapes (MAPS) [11], often investigate physical features of streets (sidewalk width, presence of the sidewalk, crosswalks, traffic lights, building height, traffic volume, trees) using audit tools. Perceived measures, such as the Neighborhood Environmental Walkability Survey (NEWS) [12], in contrast, often report residents' perceptions of their surrounding urban design using interviews or self-administered questionnaires. However, those physical attributes collected from objective measures may not reflect "people's overall perceptions of the street environment" [13]. Meanwhile, the perceived measures often face the issues of measurement reliability [14]. Lin and Moudon [15] have also suggested that objective measures of the built environment show a stronger association with physical activity than the subjective ones. In that context, only a few tools, including the tool developed by Ewing et al. [16], have been able to overcome the lack of objectiveness in measuring perceived urban design qualities. They proposed a conceptual framework explaining the process of how the physical features of the environment are perceived by people. The physical features of urban spaces will create the urban design qualities which are perceived differently by different users and lead to their own perception and reactions [17]. Based on their framework, they developed procedures to objectively measure urban design qualities of the walking environment. They did this by relating physical features of urban design qualities to five urban design qualities (imageability, enclosure, human scale, transparency and complexity) and then validated the features (an established tool) in New York [13,18]. The tool has made the subjective urban design concepts more transferable and easier to measure objectively.

Despite the significant effort in developing measurement tools for microscale urban design, the evidence for the impact of microscale urban design remains limited due to the field approach that requires considerable time and cost even for very small scale studies [19]. This highlights why there are so few microscale urban design studies, with even fewer from low- and mid-income countries in Asia. It is important to see whether findings on this research topic from Western cities can be applied to those Asian cities. Most of the cities in low- and middle-income countries in Asia are now undergoing rapid urban development [20]. Hence, there are valuable opportunities to develop or adopt a better urban design that supports active lifestyles and promotes sustainability. Research to fully understand the impact of characteristics of microscale urban design is essential to develop

suitable urban design policies and strategies. In low- and middle-income countries, the microscale urban research approach is often ideal than the macroscale approach for many reasons. Firstly, fine-grained geographical data, which are still challenging to access even in high-income countries, are often insufficient, inconsistent or not available and are costly to attain in low- and middle-income countries [21]. Secondly, urban forms in low- and middle-income countries throughout Asia such as Vietnam are often high-density with a vibrant mix of uses [20], which usually come from historical fluctuations and unregulated development rather than official planning [22]. Therefore, focusing on analyzing microscale urban design, instead of studying macroscale variables such as density and diversity, will assist our understanding. More importantly, the microscale characteristics of the pedestrian environment can be modified at a lower cost and in a shorter time frame than reconfiguring the macroscale design [23], which fits the rapid and fragmented urban development and the limited resources of those countries.

Hanoi, the capital and the second-largest city in Vietnam, is a typical city in a low- and middle-income country in Asia. Hanoi has experienced many changes to its urban development over more than 1000 years. The various changes have resulted in multilayered urban structures with five different urban typologies. The present paper assesses the microscale urban design qualities across the various urban typologies identified within Hanoi and explores whether urban design qualities reflect the differences between urban typologies.

2. Materials and Methods

2.1. Materials

The five urban typologies

As highlighted in the literature [24,25], Hanoi has five typical urban typologies, namely the Ancient Quarter, the French Quarter, the Collective Housing Quarter, the New Urban Area and the Urbanized Village Area. The Ancient Quarter, initially comprising 36 commercial guild streets, was established in the 11th century during the feudal periods, and since then it has become the center of Hanoi. The Ancient Quarter is characterized by ancient architectural heritage including temples, pagodas, and ancient traditional shophouses. Having narrow streets and sidewalks, the Ancient Quarter features a dense street network with a high intersection density, and the road–area ratio is up to 23.5% [26]. The acceleration of Western foreign influences started with the French colonization (1873-1954), resulting in the establishment of the French Quarter [27]. The French colonial style of architecture and planning was expressed through various buildings, mansions, villas and landscape spaces such as parks and lakes along with a gridlike street network of wide avenues and sidewalks. After independence from French colonization in 1957, Vietnam followed socialism, taking the design from the USSR as a model [27]. From the 1960s, models of Soviet-style collective neighborhoods were constructed across Hanoi. These neighborhoods, often called Collective Housing Quarters or "KTT" in Vietnamese, were designed to accommodate 7000 to 12,000 inhabitants and formulated by typical four- to five-storied residential apartment buildings as the core structure and public facilities such as parks, community courtyards, schools, kindergartens and markets. From 1965 to 1975, many parts of Hanoi were destroyed due to the war and rebuilt. Although the process of transforming villages, especially those near the city center, into urban settlements has been happening for many decades, the most rapid urbanization in Hanoi only happened when the economic reform, the *Doi Moi*, was initiated in Vietnam in 1986. Without planning and infrastructure development, many villages have been urbanized rapidly to meet the demand for housing during the period of economic growth; this urban typology is referred to as the Urbanized Village Area. These areas are characterized by the dominance of self-built houses and organic road networks consisting of many narrow, long and winding streets that were informally set up and connected based on the former village streets. From the 1990s, new residential projects have been planned and implemented across Hanoi, resulting in various New Urban Areas. These areas feature modern housing typologies

including high-rise apartments and large detached houses, along with a high standard of public services including new transportation networks [24]. The characteristics of these five urban typologies are summarized in Figure 1, and the distribution of typologies across Hanoi is illustrated in Figure 2.

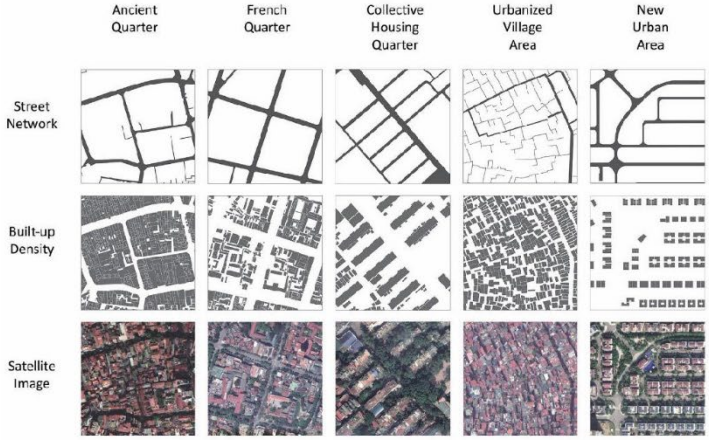

Figure 1. Spatial characteristics of the five urban typologies.

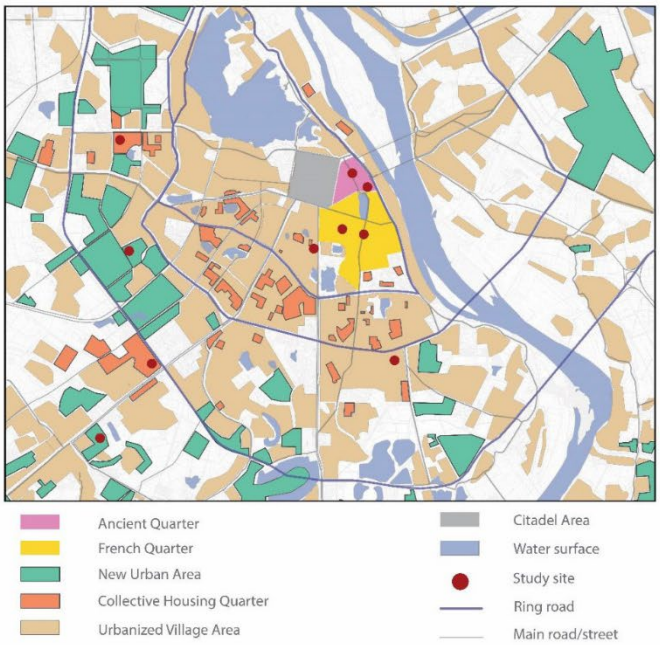

Figure 2. Distribution of the five urban typologies and study sites.

2.2. Methods

2.2.1. Site Selection

A sampling frame comprised various wards (Vietnamese third-tier administrative subdivisions) of Hanoi. The eligibility criteria for the inclusion of a ward were as follows: (1) belongs to an urban district and (2) features one of the five identified urban typologies. All wards were divided into five clusters according to their urban typologies. Two wards from each cluster were randomly selected for the study sites. The researchers then selected four streets in each study site. If any ward had fewer than four streets, the largest main alleys were chosen. The final sample comprised ten randomly selected wards with forty streets. The selected study sites are marked as red dots in Figure 2.

2.2.2. Measurement Tool

To assess the urban design qualities of the five urban typologies, we adapted the urban design quality measurement tool developed by Ewing and Clemente [18]. Ewing and Clemente's tool describes five urban design qualities:

(1) Imageability is the quality of a place that leaves distinct, recognizable and memorable images in the minds of people. Features of high-imageability spaces include physical elements that can capture, create and evoke emotions. The elements measured are the number of people on the street, the proportion of historic buildings, courtyards, plazas, parks and outdoor dining areas.
(2) Enclosure is the degree to which streets have a roomlike feeling, defined by vertical elements such as buildings, walls, trees and other vertical elements. The tool records the number of long sightlines, the proportion of street walls and the proportion of sky view to determine the enclosure level.
(3) Human Scale is the proportion of physical elements' size, texture and articulation that match the human form and correspond to people's walking speed. The elements that influence the quality of human scale include the height and length of buildings, the proportion of windows, on-street furniture and small planters.
(4) Transparency refers to the level of human activity that can be seen and perceived beyond the edge of the street or public space. The proportion of windows, street walls and the level of active use of the space are factors that affect the transparency of a street.
(5) Complexity is the level of the visual richness of a street. The variety of physical elements, specifically the numbers and types of buildings, ornaments, landscape features and human activity, contribute to the complexity of a street.

Observational data were collected using the fieldwork manual [18]. Once the various elements of the urban design quality were observed and recorded, specific multipliers along with constants derived from models developed by the tool developers, Ewing and Clemente [18], were applied to obtain the scores for the urban design qualities. Specific details on the application and derivation of the tool can be found in Ewing and Clemente's paper [18].

To capture the data from Hanoi, we amended the tool with respect to a number of definitions. For example, the definition of "historic buildings", which is determined to be "pre-WWII" in the original version, was changed to be "pre-1954" in the adapted version according to the definition of historic mansions and buildings from the Hanoi Municipal People's Committee. Additionally, the level of noise in Ewing and Clemente's tool is subjectively measured by the perception of the researcher in the field on a scale of five points [18]. To overcome this limitation of subjectiveness, we objectively measured the level of noise at each location using a smartphone app, the NIOSH Sound Level Meter (SLM) developed by the U.S. National Institute for Occupational Safety and Health (NIOSH). We classified the recorded levels of noise into five categories based on the scale derived by the American Academy of Audiology: (i) very quiet: under 30 dB, (ii) quiet: from 30 to 50 dB, (iii) normal: from 50 to 70 dB, (iv) loud: from 70 to 90 dB, and (v) very loud: above 90 dB.

2.2.3. Data Collection

A team of four research assistants visited the selected streets on weekdays only. Data collection was undertaken between September and December 2019. For each randomly selected street, observations were carried out along a distance of 100 meters. For streets in which there were multiple 100-meter segments, the team selected the most central part of the street. The researchers measured all variables comprising the five urban design qualities and counted pedestrians along the selected 100-meter segments, strictly adhering to the fieldwork manual [18] which included several steps and requirements. To summarize, it involved the researcher, at a given time point, counting people visible in a 100 m segment of the street along with counting people at the cross street to the observed site. This was repeated at four time intervals, and the average number of pedestrians was documented. For further details on the approach, please refer to the fieldwork manual [18]. All observations/measurements were attained over a one-hour period in each street.

2.2.4. Statistical Analysis

Descriptive statistics were calculated across the five urban design qualities and the total urban design quality score for each urban typology. The mean scores of individual and total combined urban design qualities for five urban typologies were Z-scored for comparison.

Multiple linear regression was undertaken to determine what urban design qualities are associated with the respective urban typology. Urban typologies were dummy coded to enter the regressions with the Urbanized Village Area as the reference category. This urban typology was selected as the reference category as it is the most common typology of the five urban typologies in Hanoi. A simple linear regression was also conducted to assess the association between the number of pedestrians and the total urban design quality score of all streets in Hanoi.

For comparative purposes, the mean scores of individual and total combined urban design qualities attained for Hanoi were compared with three studies that used the same measurement tool as used in the current paper. The three comparative cities are New York, USA; Brisbane, Australia; and Gurgaon, India [18,28,29].

3. Results

3.1. Urban Design Qualities

The mean recorded values and scores for the individual items, the five urban design qualities and the total combined urban design quality score for all urban typologies are summarized in Table 1. The Z-score of individual and total combined urban design qualities for five urban typologies is illustrated in Figure 3.

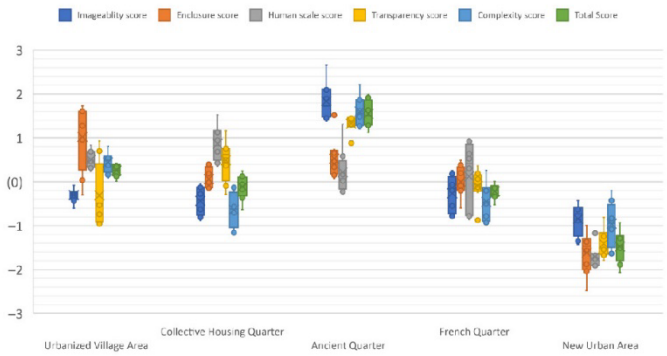

Figure 3. Z-score of individual and total combined urban design qualities for five urban typologies.

Table 1. Mean recorded values and scores for individual items and urban design qualities for five urban typologies and Hanoi.

	Urban Typologies and Individual Items	Urban Typologies										Hanoi	
		Urbanized Village Area		Collective Housing Quarter		Ancient Quarter		French Quarter		New Urban Area			
		Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score
Imageability	1. number of courtyards, plazas and parks [a]	**0.38**	**0.15**	**4.00**	**1.64**	0.63	0.26	1.63	0.67	1.88	0.77	1.70	0.70
	2. number of major landscape features [a]	**0.00**	**0.00**	**0.25**	**0.18**	0.13	0.09	0.13	0.09	**0.00**	**0.00**	0.10	0.07
	3. proportion of historic building frontage [a]	**0.00**	**0.00**	**0.00**	**0.00**	0.16	0.16	**0.34**	**0.33**	**0.00**	**0.00**	0.10	0.10
	4. number of buildings with identifiers [a]	24.75	2.72	14.63	1.61	**53.63**	**5.90**	19.00	2.09	**11.88**	**1.31**	24.78	2.73
	5. number of buildings with nonrectangular shapes [a]	24.13	1.93	**13.75**	**1.10**	**28.13**	**2.25**	21.00	1.68	25.75	2.06	22.55	1.80
	6. presence of outdoor dining [b]	**1.00**	**0.64**	**1.00**	**0.64**	**1.00**	**0.64**	**1.00**	**0.64**	**0.38**	**0.24**	0.88	0.56
	7. number of people [b]	12.38	0.25	11.66	0.23	**22.00**	**0.44**	11.66	0.23	**5.28**	**0.11**	12.59	0.25
	8. noise level [a]	3.50	−0.63	3.13	−0.56	**4.13**	**−0.74**	3.50	−0.63	**2.25**	**−0.41**	3.30	-0.59
	Total Imageability score		7.50		7.28		**11.43**		7.54		**6.52**		8.05
Enclosure	1. number of long sightlines [a]	**0.25**	**−0.08**	1.25	−0.39	1.63	−0.50	1.38	−0.43	**2.88**	**−0.89**	1.48	−0.46
	2a. proportion of street wall [b]	0.79	0.57	0.68	0.49	**0.86**	**0.62**	0.75	0.54	**0.58**	**0.41**	0.73	0.53
	2b. proportion of street wall [c]	0.81	0.76	0.69	0.65	**0.86**	**0.81**	0.70	0.66	**0.61**	**0.58**	0.74	0.69
	3a. proportion of sky ahead	**0.25**	**−0.36**	0.36	−0.51	0.36	−0.51	0.43	−0.60	**0.68**	**−0.96**	0.42	−0.59
	3b. proportion of sky across	0.08	−0.16	0.11	−0.25	**0.03**	**−0.07**	0.11	−0.23	**0.21**	**−0.47**	0.11	−0.24
	Total Enclosure score		**3.30**		2.55		2.91		2.51		**1.24**		2.50
Human Scale	1. number of long sightlines [a]	**0.25**	**−0.19**	1.25	−0.93	1.63	−1.20	1.38	−1.02	**2.88**	**−2.13**	1.48	−1.09
	2. proportion of windows at street level [b]	0.45	0.50	0.65	0.72	**0.88**	**0.96**	0.53	0.58	**0.29**	**0.32**	0.56	0.61
	3. average building height [b]	**9.34**	**−0.03**	**14.57**	**−0.04**	9.55	−0.03	10.11	−0.03	13.56	−0.04	11.43	−0.03
	4. number of small planters [b]	**3.63**	**0.18**	**13.00**	**0.65**	6.13	0.31	5.88	0.29	4.88	0.24	6.70	0.34
	5. number of street furniture and other items [b]	**7.25**	**0.29**	**17.25**	**0.69**	11.38	0.46	14.63	0.59	8.63	0.35	11.83	0.47
	Total Human Scale score		3.36		**3.70**		3.10		3.02		**1.35**		2.91
Transparency	1. proportion of windows at street level [b]	0.45	0.53	0.65	0.79	**0.88**	**1.07**	0.53	0.64	**0.29**	**0.35**	0.56	0.68
	2. proportion of street wall [b]	0.79	0.53	0.68	0.45	**0.86**	**0.58**	0.75	0.50	**0.58**	**0.39**	0.73	0.49
	3. proportion of active uses [b]	0.53	0.28	**0.91**	**0.48**	0.89	0.47	0.59	0.31	**0.22**	**0.12**	0.63	0.33
	Total Transparency score		3.07		3.44		**3.83**		3.17		**2.56**		3.21

Table 1. *Cont.*

	Urban Typologies and Individual Items	Urban Typologies										Hanoi	
		Urbanized Village Area		Collective Housing Quarter		Ancient Quarter		French Quarter		New Urban Area			
		Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score	Mean Value	Mean Score
Complexity	1. number of buildings [a]	48.88	2.44	**17.63**	**0.88**	**55.00**	**2.75**	23.25	1.16	30.25	1.51	35.00	1.75
	2a. number of basic building colors [a]	4.00	0.92	4.38	1.01	**4.88**	**1.12**	4.13	0.95	**3.88**	**0.89**	4.25	0.98
	2b. number of basic accent colors [a]	7.88	0.95	10.75	1.29	**11.88**	**1.43**	10.25	1.23	**7.00**	**0.84**	9.55	1.15
	3. presence of outdoor dining [b]	**1.00**	**0.42**	**1.00**	**0.42**	**1.00**	**0.42**	**1.00**	**0.42**	**0.38**	**0.16**	0.88	0.37
	4. number of pieces of public art [a]	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5. number of people [b]	12.38	0.37	11.66	0.35	23.88	0.72	11.66	0.35	**5.28**	**0.16**	12.97	0.39
	Total Complexity score		7.71		6.56		**9.04**		6.72		**6.17**		7.24
	Total urban design quality score		24.95		23.53		**30.32**		22.95		**17.84**		23.92

Note: [a]: both sides, [b]: observer side, [c]: opposite side. Green boldface text: max. Red boldface text: min.

Overall, Hanoi has a mean combined score of urban qualities of 23.92 with the Ancient Quarter having the highest total combined score at 30.32, followed by the Collective Housing Quarter, the French Quarter and the Urbanized Village Area at 25.11, 23.77 and 23.16, respectively. The New Urban Area has the lowest total score of urban design quality at 17.94. In terms of the individual urban design qualities, Hanoi has the Imageability, Enclosure, Human Scale, Transparency and Complexity scores of 8.05, 2.50, 2.91, 3.21 and 7.24, respectively. When assessing each urban typology, Imageability quality places the Ancient Quarter at the top with a score of 11.43, being the only urban typology that has an Imageability score above 8. In contrast, the New Urban Area is the only urban typology that has an Imageability score below 7, which is the lowest score among all urban typologies. For Imageability contributors, Collective Housing Quarter has the highest number of courtyards, plazas and parks but the lowest number of nonrectangular-shaped buildings. The Ancient Quarter has the greatest number of buildings with identifiers and people on the street and, at the same time, the highest level of noise. The Urbanized Village Area ranks first place in terms of the Enclosure with a score of 3.30, which is 2.6 times higher than the Enclosure score for the New Urban Area (1.24) and 1.3 times higher than the Enclosure score of the French Quarter (2.51). For Enclosure contributors, the Ancient Quarter and Urbanized Village Area have the best scores for proportion of street wall and sky view while New Urban Area has the lowest one. In terms of Human Scale and Transparency, the New Urban Area has the lowest scores of 1.35 and 2.56, respectively, while the remaining urban typologies both scored above 2 for Human Scale and above 3 for Transparency. For Human Scale contributors, the Collective Housing Quarter has the greatest number of street furniture and small plants. For Transparency contributors, the Ancient Quarter has 60% of windows at the street level, which is the highest, while the Collective Housing Quarter had more than 90% active ground level. The Ancient Quarter is the only urban typology that had a score above 8 for Complexity (9.04), followed by the Urbanized Village Area at 7.72. The other three urban typologies, namely New Urban Area, Collective Housing Quarter and French Quarter, all had Complexity scores below 7 at 6.17, 6.56 and 6.72, respectively. For Complexity contributors, almost all urban typologies have the presence of outdoor dining, but none of them have the presence of public art.

3.2. *Number of Pedestrians and Urban Design Qualities*

The simple regression confirmed that the total combined score of the urban design qualities is significantly associated with the number of pedestrians observed on the streets (see Figure 4).

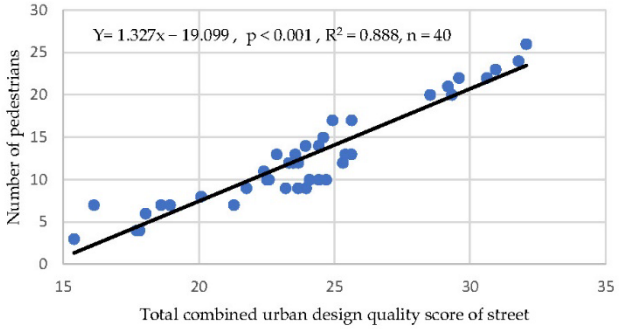

Figure 4. Correlation between number of pedestrians on the street and total combined urban design quality score of the street.

3.3. Associations between Urban Typologies and Urban Design Qualities

Table 2 highlights the findings from the regression analysis assessing the associations between the five urban typologies and the five urban design qualities. Compared with streets in the Urbanized Village Area (the reference urban typology), streets in the Ancient Quarter have significantly higher Imageability scores. For Enclosure, both the Collective Housing Quarter and the French Quarter have substantially lower scores than the reference typology. The Human Scale is not considerably different across urban typologies except for the New Urban Area. Streets in the Urbanized Village Area have a lower level of Transparency than those in the Ancient Quarter and the Collective Housing Quarter and a higher Complexity score compared with urban typologies other than the Ancient Quarter. The Urbanized Village Area has significantly higher scores across all five urban design qualities in comparison with the New Urban Area. The total urban design quality score of the Urbanized Village Area is significantly higher than that of the New Urban Area but substantially lower than that of the Ancient Quarter.

Table 2. Associations between urban typologies and urban design qualities.

	Imageability	Enclosure	Human Scale	Transparency	Complexity	Total Score
Ancient Quarter	**0.857 ($p < 0.001$)**	−0.199 ($p = 0.050$)	−0.114 ($p = 0.242$)	**0.655 ($p < 0.001$)**	**0.464 ($p < 0.001$)**	**0.516 ($p < 0.001$)**
Collective Housing Quarter	−0.052 ($p = 0.470$)	**−0.385 ($p < 0.001$)**	0.146 ($p = 0.136$)	**0.321 ($p = 0.001$)**	**−0.433 ($p < 0.001$)**	−0.146 ($p = 0.105$)
French Quarter	0.017 ($p = 0.811$)	**−0.409 ($p < 0.001$)**	−0.151 ($p = 0.125$)	0.087 ($p = 0.348$)	**−0.360 ($p < 0.001$)**	**−0.190 ($p = 0.001$)**
New Urban Area	**−0.217 ($p < 0.010$)**	**−1.057 ($p < 0.001$)**	**−0.885 ($p < 0.001$)**	**−0.439 ($p < 0.001$)**	**−0.561 ($p < 0.001$)**	**−0.692 ($p < 0.001$)**
R-Squared	0.890	0.789	0.798	0.818	0.861	0.936

Note: Boldface font indicates that the coefficient is statistically significant. Urbanized Village Area is the reference urban typology.

3.4. Comparison of Four Cities

Table 3 shows the mean score of five urban design qualities and the total score for New York, Brisbane, Gurgaon and Hanoi. Gurgaon has the highest total combined urban design quality scores at 25.54, followed closely by Hanoi at 23.92. At a much lower level, New York and Brisbane share similar total scores of 17.04 and 17.69, respectively. Despite having levels of both Imageability quality and Complexity above 10, Gurgaon's score of Enclosure quality is only 0.93, which is the lowest among the four cities. Brisbane ranks first in Transparency quality, just 0.07 points above Hanoi.

Table 3. The individual and the total combined score of urban design qualities for New York, Brisbane, Gurgaon and Hanoi.

Urban Design Quality	New York (USA)	Brisbane (Australia)	Hanoi (Vietnam)	Gurgaon (India)
Imageability	3.58	4.68	8.05	10.01
Enclosure	3.06	2.09	2.5	0.93
Human Scale	2.93	3.21	2.91	1.69
Transparency	2.66	3.28	3.21	2.84
Complexity	4.81	4.43	7.24	10.07
Total score	17.04	17.69	23.92	25.54

4. Discussion

Overall, Hanoi has remarkably high urban design qualities across the city. According to the results, streets in the areas that share the same urban typology tend to have similar scores of urban design qualities even though their locations are considerable distances apart spatially. The finding suggests that the unique urban typologies have an impact on the quality of urban design. Therefore, the authors will not discuss the urban design qualities of individual streets but instead focus on addressing the variation of the five urban design qualities across the urban typologies studied.

4.1. Imageability

The differences in the Imageability scores between the urban typologies are substantial. As expected, the Ancient Quarter (the tourist center for Hanoi) had a vast number of people on the street and many unique shops, restaurants and hotels reflecting the high density of commercial activity here, which led to a high score for building identifier and on-street people. The Imageability of the Ancient Quarter is also boosted by the distinct architecture comprising a mix of ancient houses with modern residential and commercial buildings. In contrast, the French Quarter, the Collective Housing Quarters and the Urbanized Village Areas comprise both positive and negative features providing a balanced Imageability score. For example, the Collective Housing Quarters have numerous community courtyards, but the scores for identifiers and unique shape are low as a consequence of the rectangular-shaped buildings, which are typical characteristics of the Soviet-style apartment blocks. These apartment blocks are usually renovated informally with many extended structures to create extra rooms that are locally called "chuong cop" (tiger cages) [30].

Despite lacking open spaces, the Urbanized Village Areas have a large number of nonrectangular-shaped buildings due to the high building density and the popularity of unregulated self-built dwellings in these locations. The French Quarter receives a good score for imageability due to the heritage French colonial architecture; however, the processes of conservation, privatization and commercial redevelopment, both formally and informally, have changed the structure and appearance of these buildings significantly [31]. New Urban Area ranks as the poorest for Imageability. Although having a low noise level and many open spaces, the urban design in these areas is generic and unmemorable. The dominance of private residential townhouses and villas leads to few people and activities on the streets.

Overall, the positive features of the Imageability of Hanoi are the mixed architecture and the vibrant streets are reflected by a large number of nonrectangular-shaped buildings and people on the street, as well as the presence of outdoor dining across most urban typologies. However, reduced urban design qualities are attributed to the lack of open spaces, which is a consequence of the traditional compact urban form, as well as the recent densification leaving few green open spaces [32]. The vibrant atmosphere on the street across the various urban typologies makes the neighborhoods memorable but simultaneously creates considerable noise, which reduces the Imageability quality. The noise pollution in Hanoi is predominantly the result of high-volume and congested traffic, to which poor urban design is one of contributing factors.

4.2. Enclosure

The high-density urban form in Hanoi enhances the Enclosure design quality significantly. The Urbanized Village Area is the leading typology with respect to this design quality feature. As seen in Figure 1, the Urbanized Village Areas feature an organic street pattern characterized by small streets and alleys that "start and end, curve back and forth, seemingly at random" [33]. Although the building height is limited in these areas, the high density of houses together with the system of narrow streets and alleys create a high proportion of street walls and a low proportion of sky view, resulting in a roomlike quality for spaces.

In contrast, the New Urban Areas have few street walls, but they do have a high sky view due to the wide roads and pavements, large setbacks and breaks in visual continuity with many gaps between buildings. The gaps can be either "soft gaps", defined as open spaces between buildings such as frontal or surrounding yards and gardens, or "hard gaps" that are unused lots or spaces [34]. While irregular street layouts in Urbanized Village Areas can bring up visual termination points that enhance the sense of enclosure, rectilinear street patterns in New Urban Areas create many long sightlines that undermine the sense of enclosure significantly [18].

4.3. Human Scale

There are few differences in scores for the Human Scale design quality across the urban typologies in Hanoi. This finding is explained by the reduced height of buildings and the high number of small planters and street furniture. This is a direct result of the planning restrictions in Hanoi which restricted the height of buildings in most parts of the city other than the New Urban Areas where high-rise apartment towers were and still are permitted. In the inner city, houses often have a height of 10–13 meters and only 6-8 meters in the case of the Ancient Quarter [35]. The two-story facade of tube houses, which are the most popular dwelling typology in the Ancient Quarter, offers ideal conditions for audiovisual communication between the residents and people from the street, creating a very human-scaled streetscape [36].

Since there are limited open spaces in a dense city such as Hanoi, people use streets and sidewalks as a temporary extension of their small living spaces, which makes each street very lively. Having a vibrant street life, street furniture and small planters are often set up informally. Sidewalks are considered as a semipublic semiprivate space [37] and used for all kinds of activities from social meetings to working, playing, cooking or even bathing children. That multifunctional dimension is unique to Asian streets and opposes the concept of one-space one-function which is prevalent in Western urban design [38].

Despite the minimal variation between urban typologies, the Urbanized Village Areas still stand out in terms of Human Scale quality, followed by the Ancient Quarter. Although suffering from overcrowded traffic, streets in the Ancient Quarter are traditionally well proportioned in relation to the human body since they were originally designed for walking during the feudal periods. In other settings, although street network and urban design in the Urbanized Village Areas were not planned and designed carefully and were sometimes are even set up informally, they still well fit the human form due to the nature of any informal system that is to serve the most basic daily human activities. The absence of long sightlines in Urbanized Village Areas also contributes to the high Human Scale quality of this urban typology.

4.4. Transparency

There are only minor differences in Transparency design scores across the five urban typologies except for the New Urban Area. Although Hanoi does not have a regulation for street-level windows like other cities, the dominance of shophouses [39] and very high commercial activities across the city results in a high proportion of windows at the street level (61%), which increases the Transparency design quality. Due to the narrow width of Hanoi street houses, shop facades are open to the street to encourage entry, at the same time creating a high degree of ground-level transparency between indoors and out. Each shop becomes the "social window" [40] that opens up to the social platform which is the front street. Shop owners and people on the street can easily have audiovisual communication that sometimes happens from the opposites sides of the street [36]. However, due to the increasing level of noise and air pollution in Hanoi, glass walls have been used extensively. Although the use of glass facades reduces the social aspect to some extent, the transparency in the form of windows and open doorways still remains [40].

On the other hand, high solid walls or fences around large government buildings and private residential villas in the French Quarter and the New Urban Areas reduce the

Transparency quality significantly. In New Urban Areas, the traditional shops are often replaced by shopping malls, which can provide the neighborhoods with a nonpolluted indoor shopping environment, but at the same time, they reduce the Transparency quality and the social environment of the streets there [40].

4.5. Complexity

As with most of the design qualities, the Ancient Quarter scored highest in the design quality Complexity. Due to the intense densification of Hanoi in relation to the built environment and population density, as well as the dominance of narrow tube houses, the total number of buildings on each street in the Ancient Quarter is significant. In addition, there is mixed architecture and land use together with the development of tourism services in the Ancient Quarter. Buildings and shops exhibit numerous basic and accent colors to attract customers that mostly are tourists. As expected from a center of tourism, a high number of pedestrians are observed on the streets in the Ancient Quarter, contributing to the sense of complexity.

In contrast, the New Urban Areas scored lowest. With the original intent to provide an orderly streetscape, uniform designs have been applied to the houses and buildings in these areas, creating very few types and identical building designs [41], which have reduced the sense of Complexity. Furthermore, the low built-up density together with the presence of many open spaces has lowered the score of the number of buildings.

A noticeable negative factor for Complexity quality is the absence of public art in all studied areas, which might be due to the inadequate arts infrastructure, the lack of funding and resources and the stringent government censorship [42]. In contrast, outdoor dining is present in most studied areas, thanks to Hanoi's unique street food market and lifestyle, which plays a central role in both culture and informal economy [43].

4.6. Comparing Hanoi with Other Cities

Based on the total scores from five urban design qualities, four cities can be divided into two pairs, namely (i) Hanoi and Gurgaon and (ii) New York and Brisbane, which suggests that cities in the same pair have similar urban designs. This finding also reflects the fact that Hanoi and Gurgaon are both cities in low- and middle-income countries in Asia, while Brisbane and New York are cities from high-income countries which follow the typical Western-style urban planning. The pairs of cities are also in line with the result of a study by Thompson et al. [44] on urban design types and road transport injury across the world. In that research, North American cities such as New York and Australian cities such as Brisbane are classified into the cluster of urban designs named "Motor City" characterized by low-density urban form and grid-based road networks, while Indian cities such as Gurgaon and Vietnamese cities such as Hanoi are classified into the cluster of urban design named "Informal City" characterized by low-capacity informal road networks and low rail transportation [44].

In another highlight, the Imageability and Complexity scores of Gurgaon and Hanoi are significantly higher than those of New York and Brisbane. By analyzing the original studies [18,28,29], these differences can be explained by the fact that Gurgaon and Hanoi have a high number of pedestrian movements and activities on the street, which are important elements contributing to both Imageability and Complexity qualities. In contrast, despite being one of the most walkable cities in the United States, streets in New York were found to have an average of only 5.64 pedestrians on the observer side in the study by Ewing and Clemente [18]. In contrast to Western cities, the lively street life exists naturally in the Asian urban context and is established by numerous aspects such as socio-cultural attributes, the need-hierarchy, psyche and movements, diversity of street use, informal street use and pedestrian culture [45]. While individualism is popular in cultures of Western Europe and North America, collectivism is typical in cultures of Asia, Africa and parts of Europe and Latin America [46]. People in Asia often have more open character and require less privacy than Westerners, which explains their willingness to participate in common

activities on the street. Even in the Vietnamese language, streets and roads are called "con pho" and "con duong", employing "con", a classifier word for living things, as opposed to "cai" for inanimate objects [47].

The comparison between the four cities has managed to show parts of the differences in urban design qualities between cities in low- and high-income countries and between Asian cities and Western cities. However, it is also important to note that such a comparison may contain some errors because of the considerable differences in the study objectives, the size of the samples studied and the operationalization of the Ewing and Cervante's tool in the chosen studies. The limited number of studies and geographical locations of the studied cities reduce the ability to robustly compare differing urban models and urban contexts, such as those found in European cities.

5. Conclusions

The present study evaluated the urban design qualities across Hanoi and demonstrated that urban design qualities vary across the five typical urban typologies. Imageability and Complexity are the two urban design qualities that vary the most, whilst the Human Scale, Enclosure and Transparency typologies have little variation, except for the case of the New Urban Area typology. The urban typologies together with their characteristics have an impact on the quality of urban design in both positive and negative directions. Regardless of location, streets and areas that have the same urban typology tend to have the same level of urban design quality.

Among the five urban typologies, the Ancient Quarter has the highest score for urban design qualities and the highest number of pedestrians despite being the oldest urban typology. In contrast, although being carefully designed and having a better system of infrastructure, the New Urban Areas have lower scores across all five urban design qualities. This finding suggests that the path Hanoi is following to develop the city may need to be reconsidered. Rather than adapting modern Western-style planning and urban design, it is essential to study carefully all the existing local urban forms and typologies in order to attain and apply the best urban design. It is also important to learn from lessons that have been documented from experiences of urbanization in Western countries.

In addition, the research confirmed the correlation between the number of pedestrians and the urban design quality score. The streets with better urban design qualities have a higher number of pedestrians. This finding underlines the role of street-level urban design in promoting the walkability of a place that has been recognized in previous studies.

In terms of methods, the research has successfully tested the urban design quality measurement tool constructed by Ewing and Clemente [18], which was developed for U.S. cities, which differ enormously from Hanoi where the urban context and urban design are significantly different. The study helps to fill in the gap of knowledge on street-level urban design, especially in the region of Asian mid- and low-income countries which are heavily underrepresented in the literature. The study results were also compared with previously studied cities, highlighting some significant differences between Asian and Western urban design qualities. Future validation studies of this measuring tool should be conducted in other cities from various parts of the world to better understanding the urban design qualities in different cultures and urban contexts. However, adjustments and the addition of new criteria are essential to capture the influences of different cultures and the urban context of urban design qualities. For example, when applying the measurement tool to high-density urban contexts such as Asian cities, the measures of Imageability and Complexity of the tool, which rely on the number of buildings and the number of people on street, need to be adjusted. Moreover, new criteria should be added to assess the informal and temporary elements commonly present on urban streets of developing countries such as food stalls, street markets or "semipublic semiprivate" spaces and street furniture [37], which may have considerable impact on the sense of complexity, imageability and human scale.

We acknowledge several limitations of this study. The main limitation of our research is the limited number of selected streets (n = 40). Larger sample size could have helped in providing more robust data for analysis. Other limitations include the uniqueness of Hanoi—a capital city and center of tourism in Vietnam—which may increase the data variation. For example, the number of pedestrians on streets in tourism areas may contain not only local residents but also tourists. The uniqueness of Hanoi also makes it more difficult to validate the results in other cities of Vietnam.

In conclusion, the study contributes to understanding the urban design circumstances in Hanoi, providing policymakers, planners, urban designers, architects and others with information on the street-level urban qualities for developing sustainable urban design policies, strategies and interventions that make the city more livable and ultimately promote the health of residents.

Author Contributions: Conceptualization, methodology, investigation, resources, writing, review and editing: T.P.H., M.S., J.T. and T.Q.N. All authors have read and agreed to the published version of the manuscript.

Funding: T.P.H. was supported by Melbourne Research Scholarship.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Human Research Ethics Committee of the University of Melbourne (Ethics ID: 1954948 and date of approval: 19 July 2019).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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