THE INFLUENCE OF NEIGHBOURHOOD SPATIAL CONFIGURATION ON RESIDENTS' PHYSICAL ACTIVITY AND HEALTH BASED ON THE CPTED APPROACH: A CASE STUDY OF PENANG, MALAYSIA

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by

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LIST OF ABBREVIATIONS

HPTED   Health Promotion through Environmental Design

CPTED   Crime Prevention Through Environmental Design

WC   Waist Circumference

SES   Socioeconomic Status

IPAQ   International Physical Activity Questionnaire

KPH   Kilometer Per Hour

GIS   Global Information Systems

3Ds   Density, Diversity, Design

CCTV   Closed-Circuit Television

WEMWBS   Warwick Edinburgh Mental health and Wellbeing Score

SPSS   Statistical Package for the Social Science

SEM   Structural Equation Modeling

PLS   Partial Least Squares

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PENGARUH KONFIGURASI RERUANG KEJIRANAN TERHADAP AKTIVITI FIZIKAL DAN KESIHATAN PENDUDUK BERDASARKAN PENDEKATAN CPTED: KAJIAN KES PULAU PINANG, MALAYSIA

ABSTRAK

Di dalam bidang perancangan bandar, penyesuaian ruang aktiviti fizikal dan tahap kesihatan penduduk merupakan perkara penting yang perlu dipertimbangkan. Hubungan antara penyesuaian ruang di dalam persekitaran semulajadi serta corak pergerakan manusia telah disokong secara meluas dalam kajian literatur. Walaupun terdapat banyak kajian yang telah membincangkan tentang hubungan antara persekitaran semulajadi dan kesihatan, namun ianya menunjukkan masih wujudnya jurang di dalamnya, terutama di dalam konteks Malaysia. Kajian ini telah menggabungkan dua konsep penting iaitu *Space Syntac* dan *Crime Prevention Through Environmental Desing* (CPTED) di dalam mengkaji kesan dan pengaruhnya terhadap aktiviti fizikal dan kesihatan awam. Berbeza dengan penyelidikan sedia ada, kajian ini menggabungkan dua konsep penting dan signifikan untuk menyiasat secara empirikal kesannya terhadap aktiviti fizikal dan kesihatan awam, dengan mengambil kira persepsi keselamatan dan ketakutan terhadap jenayah. Pendekatan utama yang digunakan di dalam kajian ini ialah kaedah kuantitatif sebagai proses di dalam mengumpul data bagi menjaawab setiap persoalan kajian. Dengan itu, buat pertama kalinya bagi kajian ini, pelan lokasi kajian telah dipaksi secara keseluruhannya bagi mengenalpasti rangkaian jalanraya di Pulau Pinang, dan *Syntax Space Analysis* yang paling komprehensif (iaitu; pengiraan integrasi, perhubungan, dan nilai kawalan) telah dilakukan dengan menggunakan perisian DepthMapX. Seterusnya, melalui pendekatan kuantitatif, proses pengumpulan data melibatkan pemerhatian secara menyeluruh ke atas tapak kajian yang

bertujuan untuk menilai prinsip CPTED pada skala jalanraya, serta penyediaan soal selidik yang mengandungi beberapa bahagian seperti aktiviti fizikal responden, kesihatan awam, persepsi tentang keselamatan, kebimbangan terhadap ancaman jenayah, dan penerapan elemen CPTED di dalam unit kejiranan mereka. Melihat dari aspek persampelan, kajian ini telah menggunapakai teknik persampelan sistematik berstrata untuk memilih sampel antara stratum (iaitu; integrasi global). Seramai 211 orang responden dari kawasan kejiranan telah terlibat dalam kajian ini. Teknik SEM menggunakan SmartPLS dan SPSS telah digunakan untuk menghasilkan satu analisis deskriptif dan inferens statistik. Penemuan kajian telah menunjukkan kesan positif dan signifikan di antara integrasi jalanraya, perhubungan, dan nilai kawalan (iaitu; hubungan yang lebih tinggi dengan rangkaian sekeliling) ke atas aktiviti fizikal. Namun, wujudnya pengaruh negatif secara langsung terhadap elemen penyelenggaraan persekitaran jalanraya. Manakala, penemuan kajian juga membuktikan bahawa penglibatan penduduk yang tinggi terhadap aktiviti fizikal telah melonjakkan tahap kesihatan diri kepada satu peringkat yang lebih baik. Selain itu, pelaksanaan elemen CPTED pada setiap skala hartanah juga amat penting dalam mempengaruhi tahap kesihatan penduduk yang lebih baik. Selain itu, antara penemuan lain yang penting di dalam kajian ini ialah wujudnya kesan positif terhadap kadar ukuran sintaks ruang yang lebih tinggi (iaitu; integrasi, perhubungan, dan nilai kawalan) mengenai kebimbangan terhadap ancaman jenayah. Oleh itu, kajian ini mencadangkan bahawa setiap perancang bandar harus memberikan pertimbangan tentang kepadatan atau jumlah pengguna pejalan kaki di kawasan kejiranan, bukan sahaja dari segi keselesaan semata, tetapi dengan mengambilkira faktor keselamatan (rasa selamat) di kalangan pengguna (penduduk). Berbeza dengan kajian terdahulu, kajian ini juga telah mengesahkan bahawa segmen jalanraya yang lebih mudah diakses dan dicapai tidak hanya

mempengaruhi kepada peningkatan kadar penglibatan aktiviti fizikal dan kesihatan awam, tetapi ianya turut berpotensi untuk berlakunya pelbagai isu-isu yang diluar jangka seperti penyalahgunaan ruang, fizikal, dan sosial. Oleh yang demikian, pihak berkuasa tempatan perlu mengenalpasti kawasan kejiranan yang terasing (terpisah dari kawasan tumpuan), agar dapat dinaiktaraf sebagai kawasan tarikan bagi penduduk untuk melakukan aktiviti fizikal, termasuk taman kejiranan dan laluan berbasikal.

THE INFLUENCE OF NEIGHBOURHOOD SPATIAL CONFIGURATION ON RESIDENTS' PHYSICAL ACTIVITY AND HEALTH BASED ON THE CPTED APPROACH: A CASE STUDY OF PENANG, MALAYSIA

ABSTRACT

Residents' physical activity and health are considered among the crucial urban planning concerns. The relationship between spatial configuration of the built environment and human movement patterns is widely supported in the literature. Despite the growing research on the relationship between the built environment and health, there is still a gap in the theoretical aspects, especially in Malaysian context. In this sense, this study combined the two significant and influencing concepts of Space Syntax and Crime Prevention through Environmental Design (CPTED) to empirically investigate their impact on public physical activity and health. Moreover, this study examined the mediating role of perception of safety and fear of crime in this relationship. The present study employed a quantitative research approach. In this study, for the first time, an axial map of the entire Penang Island street network was drawn, and the most comprehensive space syntax analyses (i.e., calculations of integration, connectivity, and control value) were performed using the DepthMapX software. The study further employed a survey method for the next stage of data collection, including an on-site observation checklist to evaluate CPTED principles on a street scale and a self-administered questionnaire containing several sections about the respondents' physical activity, general health, perception of safety, fear of crime, and their houses' elements of CPTED. A stratified systematic sampling method was used to select samples among stratum (i.e., global integration). A total number of 211 participants from the selected neighbourhood were involved in this study. SEM techniques using

SmartPLS and SPSS were employed to conduct the descriptive and inferential analyses. Findings showed a positive and significant effect of space syntax measures (i.e., linkage to the surrounding network) on physical activity and an indirect positive effect on health mediated by physical activity However, a negative and direct influence on the street maintenance elements. Residents with higher physical activity reported higher levels of self-rated health. Moreover, CPTED elements on property-scale were found to have an influencing factor for better health. Another significant finding was the positive effect of higher rates of space syntax measures (integration, connectivity, and control value) on residents' fear of crime. This study suggests that urban planners should consider the density of pedestrians in the neighborhoods, not only in terms of comfort but in terms of feeling of safety among users. Moreover, local authorities need to identify the most segregated areas and try to build some physical activity facilities, including neighbourhood parks or biking trails.

CHAPTER 1

INTRODUCTION

1.1   Background of the study

In recent decades, urbanization has entered the phase of acceleration all around the world and profoundly affected the social and physical structure of the cities' environment. The world's rapid urbanizing growth has led to important changes in our lifestyle, living standards, routine activities, social attributes, and health (City & Assessment, 2010). Malaysia's rate of urbanization has also increased dramatically since 1970 among Asian countries, from 25% in 1960 to about 65% in 2005, and is predicted to exceed 70% by the end of 2020 (Ho, 2008). It is widely believed that there is not sufficient attention to the health issues in environmental policymaking, especially in urban planning decisions (Pineo et al., 2017).

As well as other countries with a high pace of urbanization and industrialization, Malaysia is experiencing concern about the prevalence of insufficient levels of public physical activity. "The global estimate for the prevalence of physical inactivity among adults is 17%, ranging from 11% to 24%. Estimates for the prevalence of some but insufficient activity (<2.5 hours per week of moderate activity) ranged from 31% to 51%, with a global average of 41% "(World Health Organization, 2002, p. 61). Evidence shows that the low rate of physical activity in Malaysian young adults (those in their twenties) has led to some health problems, especially in women (Ismail et al., 2002).

Physical activities consist of various categories, including walking, jogging, biking, exercising, swimming, and dancing. It can also be grouped based on aims of leisure and utility, such as transport, professional, and household activities (L. Frank et

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al., 2003; Koohsari, Badland, et al., 2013). Several socio-ecological studies discuss that health status is affected by human behaviour and the elements of the surrounding built environment (Barton & Grant, 2006; Stokols, 1992).

Social and physical factors of the built environment, including the houses, buildings, and the whole neighbourhood, can play an essential role in physical and public health (Houle et al., 2017). During the last few decades, the focus on environmental interventions affecting public health has increased (McLeroy et al., 1988). In this sense, 'urban planning can, and should, play a role in making the impact of urbanisation on health benefits for people' (World Health Organization, 2011a, p. 2).

The significant impact of the built environment in promoting public health is a recent field of interdisciplinary research (Kent & Wheeler, 2016). The form and design of the built environment have an important role in shaping how residents travel and create opportunities to encourage them to have physical activity linked to active transport (Chen et al., 2008). Health Promotion Through Environmental Design, commonly known as HPTED, is an outcomes-focused and collaborative concept in the built environment's impact on public health. HPTED tried to explore the lessons learned from the Crime Prevention Through Environmental Design (CPTED) concept to propose the key characteristics to apply to health promotion. Those who are physically active will have considerable health benefits. One of the important determinants of physical activity is the person's immediate environment. The built environment can create both motivators and barriers to physical activity (Jackson et al., 2013).

The built environment can be planned to increase chances for routine physical activity, even in outdoor spaces, which leads to more sense of community and engagement in the local neighbourhood (Krenichyn, 2004). Practitioners and scholars

have come to appreciate the crucial role of the built environment in paving the way for people to have physical activities or discouraging them (B. Saelens & S. Handy, 2008).

Many scholars have noted that perceiving the neighbourhood as unsafe leads to poor health outcomes (Wallace, 2012). Feeling unsafe and insecure in the neighbourhood environment will make people unwilling to participate in outdoor physical activities (e.g., walking, jogging, or biking) or social interactions (Saville, 2009). HPTED states that safety includes a broader range of issues like protecting against pollution or natural hazards while implementing Crime Prevention through Environmental Design, mostly known as CPTED principles on local scales, can dramatically enhance safety and security (Cozens & Sun, 2018; Kent & Thompson, 2012).

Utilizing CPTED principles can help decrease the crime incidence opportunities provided by the built environment and better control crime attractors or preventers (Sohn & Dong, 2016). Evidence shows that the street network of a neighbourhood and its physical configuration that form the accessibility and movement patterns in a given area may affect crime risk (Wu et al., 2015). An essential concept of physical configuration analysis is using a methodology known as Space Syntax, which encompasses several techniques with great potential to analyse structural patterns of the street network and to develop an index of the movement of people in neighbourhood (Hiller & Hanson, 1984). Space syntax refers to describing, analysing, quantifying, and representing the relationships between urban spaces and buildings, or in other words, the spatial configuration in settlements and buildings. Configuration can be defined as the relationship between at least two spaces, considering the third space, up to the most, as the relationship between two spaces considering all of the existing spaces in the complex (Hillier et al., 1987; Klarqvist, 2015). Four main measures play a significant

role in space syntax leading to quantitative representations of buildings or urban layouts, including connectivity, global and local integration, and control value.

Considering both social and physical effective aspects of environments in people's physical activity and health, this study aims to investigate the effects of physical indicators, namely CPTED, Space Syntax measures (i.e., Global and Local Integration, Connectivity, and Control value) on people physical activity and health. The current study seeks to examine the impact of characteristics of the built environment, especially neighbourhood structure, on the residents' routine physical activity and health. Accordingly, the study considered the space syntax measures and CPTED, physical activity, and health by considering the social factors, namely fear of crime and perception of safety in the neighbourhood.

There are limited studies conducted on the relationship between CPTED and health outcomes (Cozens, 2002; Cozens, 2008b; J. S. Lee et al., 2016), and few studies on the relationship of the spatial configuration on the walkability of the streets based on space syntax techniques (Koohsari et al., 2015). However, the previous studies mainly examined street network layouts in European and Australian contexts and did not focus on public health or just on walking as physical activity. While routine physical activity exists in four categories in day-to-day life: transport (for example, walking or cycling), leisure (sports or recreational activities), domestic duties (housework or gathering fuel) or work (manual labour), and physical inactivity refers to having very little or no physical activity in any of the mentioned categories (World Health Organization, 2002). The current study tries to address this shortcoming in the literature by developing a comprehensive model for CPTED, Space Syntax measures (i.e., Global and Local Integration, Connectivity, and Control values), Fear of Crime, Perception of Safety,

Physical Activity, and Health. Indeed, this study examines whether people's physical activity and health differ across streets configuration and CPTED rate.

1.2   Problem statement

Insufficient physical activity substantially impacts individuals' health, and not having physical activity is considered a worldwide concern and a considerable risk factor for several chronic physical and mental diseases (United States Department of Health and Human Services, 1996). The same situation exists in Malaysia as well. Findings from the latest National Health and Morbidity Survey (NHMS) by the Ministry of Health (2019) showed that 50.1% of adults in Malaysia are overweight or obese. Moreover, 25.1% of adults are physically inactive, and only 45% of Malaysian adolescents are physically active.

It is believed that both social and physical factors of the living environment can affect physical activity and the level of public health. Social characteristics of the environment refer to those including social networks, social support, racial discrimination, social capital, and social cohesion within the neighbourhood (McNeill et al., 2006; Schulz & Northridge, 2004). It is needed to more precisely examine the physical factors that play the roles of barriers or motivators of physical activity. This is because the physical aspects of the living environment have an outstanding contribution to providing or diminishing opportunities for physical activities (Ellis et al., 2016; Laddu et al., 2021; Sugiyama et al., 2012; F. Wang et al., 2013). Existing literature indicates that urban planning developments should consider health-promoting strategies in the early stages of each decision-making (Ellis et al., 2016; H. Yang et al., 2022).

In this regard, there are two theories relevant to the built environment and health: CPTED, founded by Jeffery (1971), and HPTED, coined by Kent and Wheeler (2016)

which is based on the CPTED's lessons focused on the approach to improving human health and well-being through the design of the built environment, and providing opportunities for physical activity is one of its principles. Since neighbourhood crime and unsafety feelings have a negative impact on physical activity and health, people may decrease their outdoor activities due to a lack of safety feelings (McGinn et al., 2008). Furthermore, evidence implies that one of the major physical factors of the built environment that affect physical activity is the spatial configuration of the streets (Koohsari, Owen, et al., 2016; McCormack et al., 2021). In this regard, the space syntax theory and techniques can potentially discover an urban environment's spatial configuration (Koohsari et al., 2019; Sun et al., 2020). Therefore, in order to recognize the environmental characteristics supportive of physical activity and health, the built environment primarily should be analysed and measured considering the safety and fear of crime feelings.

Existing literature shows several studies conducted on the relationship between the built environment and physical activity rates in neighbourhoods. However, still, a few empirical studies examine the spatial configuration analysis of different neighbourhood environments and residents' physical activity (Koohsari et al., 2019; Koohsari, Owen, et al., 2016; Lerman et al., 2014; Su et al., 2019). Physical activity and spatial configuration by space syntax techniques are also profoundly untested in the Malaysian context.

Although there are studies on the relationship between the spatial configuration of urban areas and the rate of physical activity and health among dwellers, only limited studies combined safety and crime prevention elements (particularly CPTED) and spatial configuration with regard to this relationship. This study focuses on this gap in the literature by examining the CPTED features of a residential neighbourhood by

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considering its spatial configuration analysis. The study employed space syntax techniques as one of the most effective techniques for analysing the spatial configuration of the environment and its effect on people, which can shape individual and collective behaviour and health (Koohsari et al., 2015). Despite numerous studies on this topic in developed countries, there is a lack of studies on physical activity and environmental analysis by space syntax techniques in developing countries, particularly the Malaysian context.

CPTED elements and their influence on fear of crime and perception of safety have been tested within Malaysian contexts (Abdullah, Hedayati Marzbali, et al., 2013; Hedayati Marzbali et al., 2012; Sakip & Abdullah, 2012). However, a critical gap exists in the area of knowledge examining CPTED measures and feelings of unsafety concerning residents' physical activity in the Malaysian context. Nevertheless, despite numerous studies assessing the built environment features influencing physical activity and health, the development of a reliable model of neighbourhood structural analysis that encompasses both configurational analysis and safety, and crime prevention elements is lagged up to now. Studying streets' spatial configuration influence on physical activity in developing countries is required to be covered in this area of research (Su et al., 2019).

This research extends the existing literature on the topic considering Penang, Malaysia, especially due to the hot and humid climate, which can affect public physical activity. This gap justifies this research to develop a comprehensive model to measure space syntax measures and the CPTED elements in samples that have not been previously examined. Overall, the present study contributes to the existing literature by examining how the spatial configuration of the built environment, measured by space syntax techniques and the CPTED elements, can impact the dwellers' physical activity

and health, considering the mediating role of fear of crime and perception of safety in Penang, Malaysia.

1.3   Research Aim and Objectives

This study focuses on spatial configuration and street layout, emphasizing the relationship between public health and the built environment. This is because residents' routine physical activity and health are closely affected by the neighbourhood's physical layout and social characteristics. Since there are some spots in which people and especially pedestrian presence are more likely than others. Accordingly, urban decision-makers and professionals such as landscape planners and urban designers should consider the factors mentioned earlier to improve public physical activity and prevent further diseases.

This study mainly aims at investigating the impact of CPTED and street configuration on physical activity and health based on space syntax measures. Furthermore, it also seeks to investigate the relationship between the rate of physical activity and street configuration and how CPTED indicators affect residents' physical activity and health considering the social factors, namely fear of crime and perception of safety in the neighbourhood. Overall, this study attempts to achieve the following objectives:

1. To examine the impacts of space syntax measures on residents' physical activities and health in Penang, Malaysia.
2. To investigate the impact of CPTED on the perception of safety, fear of crime, and physical activity of residents in residential neighbourhoods.
3. To test direct or indirect relationships among perception of safety, fear of crime, physical activity, and health in the research area.

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4. To develop strategies to enhance physical activity and health among residents in residential neighbourhoods.

1.4 Research Questions

By identifying the aforementioned research objectives, three questions arose that need to be answered in this study:

1. What are the impacts of space syntax measures on residents' physical activities and health in Penang, Malaysia?

2. How does CPTED affect the perception of safety, fear of crime, and physical activity of residents in residential neighbourhoods?

3. Are there any direct or indirect relationships among perception of safety, fear of crime, physical activity, and health in the research area?

4. What are the strategies to enhance physical activity and health among residents in residential neighbourhoods?

1.5 Scope of the Study

This study focuses on the residential neighbourhoods in Penang, Malaysia, based on theories of Natural Movements and CPTED. According to the theory of Natural Movement by Hillier et al. (1993), as the basis of space syntax theory, the study tends to select a neighbourhood that contains a variety of global integration levels from the highest level (most integrated street segments) to the lowest level (most segregated street segments). This could pave the way for making a comparison between high and low levels of global integration because evidence shows that level of global integration has a significant relationship with the movement patterns of pedestrians (Hillier et al., 1993; Koohsari, Owen, et al., 2016; Raford & Ragland, 2004). Additionally, Baran et al. (2008) indicated that more walking in neighbourhood is associated with global

integration. Evidence also revealed that the global integration of space is correlated to the users' perception of safety (X. Li et al., 2019), and crime rates and fear of crime play a significant role in an active lifestyle (C. Lee et al., 2016). CPTED theory is also known to significantly affect the fear of crime and perception of safety.

Based on its aim and objectives, the present study intends to select a neighbourhood in the Malaysian context based on the syntax measure of global integration and crime hotspots. Therefore, the study area is determined through the overlay of global integration and residential crimes hotspot maps. To this end, the analysis map of global integration was overlaid with the residential crimes hotspot map and led to the selection of Bayan Lepas (Mukim 12, Barat Daya district) as the research area with various levels of global integration within the hotspot of crime distribution area in Penang Island. This study mainly focused on terraced and semi-detached properties since a large number of the landed houses in the study area are terraced and semi-detached. Terraced houses made up 21.3% of the total residential units in Penang (NAPIC, 2020). The number of existing landed properties, including terraced and semi-detached house units minus the shophouses, and vacant and non-residential blocks in the study area, is 2215. The data collection was conducted in three months, from June to August 2021. The population for the present study consists of households living in terraced houses within the study area, including adults aged 18 and above in order to be able to answer the questionnaire.

1.6   Significance of study

It is widely proved that physical activity is crucial for physical and mental health benefits. As human life develops in many areas, a particular need is to improve living and health conditions. Rapid urbanization is better be accompanied by developed urban

neighbourhoods. Accordingly, policy attempts to emphasize modifying neighbourhoods to achieve the goal of enhancing physical activity. Exposure to environmental impacts occurs in several contexts, of which the residential neighbourhood is the most important (Groenewegen et al., 2018).

Evidence suggests that neighbourhood spatial configuration, perception of safety, and the elements, which lead to a decrease in crime occurrence, are associated which the level of residents' physical activity (Foster & Giles-Corti, 2008; Koohsari et al., 2014; Richardson et al., 2017; Ruijsbroek et al., 2015). Many physical activity programs are organized globally, but it seems they have not been effectively helpful due to their focus on the individual level. Nevertheless, health promotion and physical activity have long endorsed the significance of living environment interventions. A similar situation exists in Malaysia (W. L. Cheah et al., 2012).

The latest National Health and Morbidity Survey (NHMS) by the Ministry of Health (2019) showed that 25.1% of adults are physically inactive, with the Health Ministry warning that the matter was reaching an alarming level and lack of physical activity is the main reason for 16.4% of this country's deaths. Global Observatory for Physical Activity (GOPA) (ISPAH, 2019) was created in 2012 to improve insufficient physical activity worldwide. Ministry of Health in Malaysia also published the National Strategic Plan for Active Living, providing strategies to promote an active lifestyle among Malaysians (M. o. H. Malaysia, 2018). The present study, therefore, contributes to urban planning methods regarding promoting the residents' physical activity. Accordingly, the current study findings align with the GOPA programme in Malaysia.

On the other hand, evidence shows that the crime rate is among the vital factors for having physical activity on street and neighbourhood scales (Knapp et al., 2019). Penang also accounted as one of the four crime hotspots in Malaysia. The crime index

ratio per 100,000 population for Malaysia in 2019 improved to 256.6 as compared to 273.8 in 2018; however, the crime index ratio for all states of Malaysia decreased except for three states; one of them is Pulau Pinang (3.7%) as reported by Department of Statistics, Malaysia (2020). There is a lack of such studies in Malaysia and urban regional contexts regarding crime, safety, and the spatial configuration of neighbourhoods and residents' physical activity in Penang, Malaysia, as there is minimal research conducted in this field. The environment's climate is also an essential factor in physical activity performance (González-Valero et al., 2019; Harwood et al., 2015); therefore, the pattern in Malaysia, given the hot and humid climate, may differ compared to other regions. In this sense, the findings of this study can contribute to the relevant body of knowledge.

Finally, health and well-being are essential for achieving the United Nation's Sustainable Development Goals (SDG #11) which seeks to enhance safe, inclusive and sustainable urbanization and improving strategies for improving physical activity plays a vital role in promoting public health. Creating neighbourhoods that are supportive of physical activity can effectively counter the rapidly growing inactivity and motivate the entire population to gain from a physical activity-enhancing built environment and change the way we live in our daily lives (Devarajan et al., 2020). Therefore, the findings of this study can provide more information for the consideration of planning strategies to promote physical activity and prevent the built environment barriers to physical activity contributing to achieving the SDGs.

The hypothesized framework is based on multidimensional measures of the constructs using structural equation modeling (SEM), which helps to gain more reliability in measuring the variables.

1.7 Thesis Methodology

The present study is cross-sectional and conducted in a residential neighbourhood with various street network configurations based on their street network pattern. The study samples are adults aged 18 and above. Based on the research questions and objectives, it adopted a quantitative approach and included three parts. Firstly, in order to select the study area, the spatial configuration of the entire Penang Island was analysed by calculating space syntax measures using DepthMapX software. Secondly, the data collection encompassed an on-site observation of the selected neighbourhood environment to measure the CPTED elements at the street and neighbourhood levels. Thirdly, physical activities, general health, CPTED elements on the property scale, fear of crime and perception of safety were measured via a questionnaire survey. A detailed chapter of the research methodology is provided in chapter 3.

1.8 Operational Definitions of Terms Used in the Study

Some terms used in the present study need to be precisely defined. The following addresses definitions of the built environment, neighbourhood, physical activity, spatial configuration, perception of safety, fear of crime, and health.

Built environment: The built environment consists of man-made aspects of urban design, a diversity of land uses such as offices, houses, and transportation systems like roads, sidewalks, and bicycle lanes. Besides, it includes patterns of individuals' activity within the physical environment (Handy et al., 2002; Tewahade et al., 2019). In this study, the built environment is mainly limited to the urban neighbourhood in which individuals live.

Neighbourhood: Neighbourhood is not just the artifact of urban scholars. Indeed, the neighbourhood area comprises "the bundle of spatially based attributes associated with clusters of residences, sometimes in conjunction with other land uses" (Galster, 2001, p. 2112). Quite simply, by "neighbourhood area," we mean the group of houses and the shared residential area (defined common area) that usually has a name (N. A. Ross et al., 2004). "Each of these dimensions of the built environment can also be measured for an entire metropolitan area, usually as the distribution of neighbourhoods along a particular dimension" (Handy et al., 2002, p. 66). In this study, neighbourhood refers to an area with almost identical spatial conditions and characteristics, separated from adjacent areas with a main road, highway, or a recognizable indicator.

Physical activity: Physical activity is any body movement provided by skeletal muscles that leads to energy expenditure. Physical activity comprises recreational, work-related, and leisure-time activities (Caspersen et al., 1985). In this study, we refer to all three aforementioned categories that are performed within neighbourhood areas.

Spatial configuration: In this study, spatial configuration refers to connected relations in a system, in other words, how spaces relate to each other within a system (Hillier et al., 1984), and in the present study, this was evaluated by space syntax measures.

Perception of Safety: Perception of safety or perceived safety in this study refers to what extent residents feel safe in their neighbourhood. In this study, Perception of Safety and Perceived Safety are sometimes used interchangeably throughout the text.

Fear of Crime: This study refers to the fear of crime as the extent to which respondents worry about encountering or being a victim of specific crime types, such as house burglary or being robbed.

Health: In this study, health refers to self-rated or perceived health that are sometimes used interchangeably throughout the text. Self-rated health refers to how people perceive their own health status, including physical and mental health.

1.9   Organization of Chapters

In this section, the organization of this thesis is clarified, describing the chapters and their structures more precisely. The present thesis is arranged in six chapters as follows:

- Chapter 1 begins with a review of the study background and the problem statement, which is a description of gaps in previous studies, the justification of the present study, and the issues this study is about to address. Subsequently, the research aim and objectives are represented following the research questions. An explanation of research scopes comes next, which is followed by a clarification of the research significance. A brief description of the thesis methodology comes next, and the chapter ends by discussing the operational definition of the terms used.

- Chapter 2 firstly focuses on the built environment's overview and its relationship with health issues, followed by articulating the different aspects of the built environment affecting physical activity and health. The next is introducing space syntax theory and its measurements in analyzing an urban area, as well as an assessment of the relationship between the spatial configuration of urban spaces and physical activity and health. This is followed by discussing CPTED theory and its elements. Then the chapter outlines a broad review of the existing studies on the physical attributes of the built environment, which affect physical activity, perception of safety, fear of crime, and health. A review of the literature

on the relationships between the perception of safety, fear of crime, physical activity, and health comes next. Then the physical activity features in Malaysia are examined. This is followed by examining the relationship between CPTED and perception of safety, fear of crime, physical activity, and health, following the application of CPTED techniques in Malaysia. Finally, the hypothesized model of the study is demonstrated.

- Chapter 3 fully introduces the research design and presents the methods of data collection employed in this study. The criteria for selecting the study area are then explained. Sampling size and sampling method are then discussed. This is followed by describing survey instruments based on syntactical analysis, personal observation, and questionnaire survey according to previous studies. Finally, a description of the data analysis method.

- Chapter 4 covers the result extracted from the data analysis. It then explains the differences of the variables according to spatial design. Then it continues by presenting the relationship between CPTED measures and other variables.

- Chapter 5 aims to summarize the thesis. The conclusions of the study results are compared to the available literature, and then the study limitations are described. Lastly, implications and recommendations for the landscape planning area and the recommendations for future studies are consequently performed.

1.10 Summary

This chapter of the thesis begins with the background of the study and further describes the problem statement and research gap. This is followed by the research aim and objectives, research questions and scope of the study. Next, the significance of the study and a brief explanation of the thesis methodology is presented. The chapter ends with the operational definitions of the terms used and the organisation of the thesis chapters.

CHAPTER 2

THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

2.1   Introduction

This chapter first focuses on the built environment's overview and its relationship with health issues, followed by articulating the different aspects of the built environment affecting physical activity and health. The next is introducing space syntax theory and its measurements in analyzing an urban area, as well as an assessment of the relationship between the spatial configuration of urban spaces and physical activity and health. This is followed by a discussion of CPTED theory and its elements. Then the chapter outlines existing studies on the physical attributes of the built environment, which affect physical activity, perception of safety, fear of crime, and health and the relationships among them. Then the physical activity features in Malaysia are examined. This is followed by examining the relationship between CPTED and perception of safety, fear of crime, physical activity, and health, following the application of CPTED techniques in Malaysia. The final part includes the conceptual framework of this study based on the existing literature and theories.

2.2   Concepts and Theories of the Built Environment and Physical Activity

The contexts in which people live are increasingly known as a crucial factor in shaping their wellness (Stokols, 1992). A growing number of studies indicate that many neighbourhood attributes are significantly associated with physical activity (Kaczynski, 2010). One of the essential steps in discovering the impacts of the neighbourhoods in forming physical activity is to conceptualize and measure the built environment (Sallis, 2009). Regarding neighbourhood's features related to physical activity, three main

concepts in the existing literature are employed to measure the built environment, including (i) Natural Movement, (ii) Neighbourhood Walkability, and (iii) Density, Diversity, and Design (3Ds). In the following, a comprehensive description of these concepts is presented.

2.2.1   Natural Movement

Natural movement, which was coined by Hillier et al. (1993) as the basis of space syntax, argues that urban layout is the "primary generator of pedestrian movement patterns." This theory indicates that the spatial configuration of the urban layout itself provides attraction inequalities and paves the way for activities and movements regardless of land use attractors. In other words, "in urban systems, the configuration is the primary generator of pedestrian movement patterns, and, in general, attractors are either equalisable or work as multipliers on the basic pattern established by configuration" (Hillier et al., 1993, p. 31).

Multiple studies reported high correlations between street connectivity and pedestrian flow. For example, in a study by Read (1999) in five Dutch cities, the findings indicated that a higher degree of street connectivity has more significant natural movement. Koohsari, Owen, et al. (2017) revealed in their study that local destinations partly accounted for relationships of street patterns with residents' travel behaviours. The role of local destinations as a mediator can be explained by the concept of 'natural movement' that suggests more connected street patterns are likely to attract more pedestrians, therefore a higher chance of having more destinations. Urban layout seems to be structured in order to create, "by the generation and channelling of movement, a kind of probabilistic field of potential encounter and avoidance" (Hillier et al., 1993, p. 32). He explained that this statement does not claim that natural movement is not a

cultural phenomenon. In contrast, it includes various forms in various contexts, reflecting the spatial logic of the urban street network. The urban layout is a cultural product because it creates encounter fields with different structures through natural movement. These differences mainly include various degrees and types of possible interactions between different categories of people: different genders, inhabitants and strangers, social classes, adults and children, etc.

2.2.2   Neighbourhood walkability

Neighbourhood walkability consists of the built environment's attributes that promote physical activity, such as active transportation (Arvidsson et al., 2013). It is composed of three parameters: residential density, street connectivity, and land use mix (L. D. Frank et al., 2005; Leslie et al., 2007).

Residential density refers to the proportion of residential units to the area allocated for residential use in a hectare. Intersection density is the proportion of the number of intersections in a square kilometre. Land-use mix can be classified into five categories of residential, commercial, recreational, institutional, and others (Ester Cerin et al., 2007; L. D. Frank & Pivo, 1994; Lotfi & Koohsari, 2011).

The walkability index may be calculated by using the following expression (L. D. Frank et al., 2010):

Walkability = [(2* intersection density) + (net residential density) + (retail floor area ratio) + (Land mix use)]

Evidence shows that neighbourhood walkability positively correlates with physical activity time (Sallis et al., 2009). Walkability is especially linked to the sort of physical activity, namely active travel. Regular walking is widely reported to have a

relationship with physical and psychological health benefits (Ellis et al., 2016; Hamer & Chida, 2008).

2.2.3   3Ds

In their study, Cervero and Kockelman (1997) proposed a concept to conceptualize the characteristics of the built environment form that might be pertinent to physical activity and health outcomes. The concept was called 3Ds including Density, Diversity, and Design, and the way these aspects are linked to the individuals' travel behaviour. The results showed that high population density, diverse land uses, and pedestrian-friendly design in a neighbourhood significantly promoted active travel choices and overall physical activity. The 3Ds concept was later extended to develop the concept of 'neighbourhood walkability,' including the residential density (Density), land use mix (Diversity), intersection density (Design), and net retail area ratio (Design) (L. D. Frank et al., 2010; Koohsari, Owen, et al., 2016).

2.3   Analytical Methods of Urban Design

Given the shortage of success in individual approaches to behaviour changes, including education, motivation, or guidance, the built environment's features in which people live and communicate are identified as significant potential determinants of a physically active lifestyle. In order to specify the built environment features that are encouraging for physical activity, first, the built environment is required to be operationalized and measured (Koohsari et al., 2019).

Analytical methods are nearly a novel approach in urban planning, which was first initiated in the late 19th century. However, during the last few decades, theoreticians, including G. R. Collins et al. (2006), Sitte (1979), and Geddes (2019),

suggested analytical-based methods in this regard (Karimi, 2012). On the other hand, Lynch (1960) tried to analyse the urban environment with an approach to the perception of the leading urban components, including nodes, paths, districts, edges, and landmarks. The urban grid analysis of Alexander (1964), which encompassed graph representation and graph analysis, enhanced more systematic thinking about design. More recently, 3D modelling has emerged that is mainly used in the presentation of a structure, however, partly employed to analyse some particular aspects of the urban design (Montello, 2007). Finally, the introduction of Geographical Information Systems (GIS) has also directly influenced analytical methods in urban transportation, planning, and design.

The aforementioned analytical methods mostly have a significant challenge that is not becoming an integral part of the urban design process. Even if they do, they cannot provide an accurate assessment that combines creativity and research into one approach in the design process (Karimi, 2012). Urban planning patterns are recognised the important tools to promote public health. The calls for these two disciplines decreased in the 20th century, but, currently, efforts have been made to rejoin them (Boarnet & Takahashi, 2011; Giles-Corti & Whitzman, 2012; Sloane, 2006). Consequently, "urban planning can, and should, play a role in making the impact of urbanisation on health beneficial for people" (The World Health Organization, 2012, p. 2).

Generally, the influence of urban structure on physical activity, particularly walking, has been examined based on the average areas of properties and route directness. Literature suggests that smaller block sizes, shorter distances between intersections, and accessibility to more direct paths encourage people to have a more active transport style. For example, when routes are shorter and more direct to reach, given the higher intersections, walking to stores (Handy, 1996) and other destinations

like shops, markets, and cafés/restaurants has a greater probability (C. Lee & Moudon, 2006). Besides, when the blocks are smaller and pedestrian sidewalks are more available and well maintained, people are motivated to have an active means of transport to neighbourhood centres (Hess et al., 1999).

Many studies have focused on the influence of street network patterns on physical activity. Some of them directly suggest the connectivity of street networks as an aspect that impacts accessibility and walkability (Ozbil et al., 2011). The measures include the number of intersections per area (J. Kerr et al., 2007), block size per area (Krizek, 2000), cul-de-sacs per area or road mile, the ratio of four-way intersections (Handy, 1996; Parks & Schofer, 2006), the proportion of intersections to cul-de-sacs, or the average distance between intersections (Rodriguez et al., 2006).

Generally, three key methods have been employed to explore the environmental features encouraging physical activity (Brownson et al., 2009). The first method includes self-reporting features of the built environment that reflect how individuals perceive and interpret their neighbourhood environments, such as accessibility of stores, sidewalk quantity and quality, safety, and aesthetic aspects (B. Saelens et al., 2003; Weiss et al., 2010). The second method encompasses the objective evaluation through on-site observations that is mostly used to systematically measure built environment features in micro-scale aspects within neighbourhood streets (Hoehner et al., 2007), trails, and sidewalks (Troped et al., 2006), and parks (Kaczynski et al., 2012). The third method involves data from existing data sets to be layered and analysed with GIS (Brownson et al., 2009).

However, an important concern regarding these measures is that they cannot assess the spatial configuration of street networks in the built environment that is highly associated with the residents' active movements (Hillier & Iida, 2005; Koohsari et al.,

2014). On the other hand, the difficulty of accessing the relevant geographical data is a limitation in calculating the attributes of an environment related to physical activity support. Net retail area ratio, land use mix, and net residential density need parcel-level information about land use and retail floor area, which is practically unavailable or hard to collect (Lotfi & Koohsari, 2011; Salvo et al., 2014). Another group of studies that takes a configurational approach is associated with space syntax (Hillier, 1996a; Peponis & Wineman, 2002). This covers measuring the accessibility of all network parts considered from each street element. Table 2.1 demonstrates a brief categorisation of analytical methods of urban design.

Table 2.1 Analytical methods of urban design

Analytical methods of urban design	Sources
Using the perception of main urban components	Lynch (1960)
Graph analysis	Alexander (1964)
Self-report assessment of the built environment	Handy (1996) B. Saelens et al. (2003) Weiss et al. (2010)
Objective assessment through field observations	Troped et al. (2006) Kaczynski et al. (2012)
3D modelling	Montello (2007)
Geographical Information Systems (GIS)	Birkin (1996)
Street networks	Ewing and Cervero (2001) Southworth and Owens (1993) Rodriguez et al. (2006) Song and Knaap (2004) Ozbil et al. (2016)
Street configuration (Space Syntax)	Hillier et al. (1983) Bafna (2003) Dursun (2007) Sugiyama et al. (2012) Klarqvist (2015) Koohsari et al. (2019)

Space syntax, developed at the Unit for Architectural Studies, University College London by (Hillier et al., 1983), is a set of techniques for representing,