

Influence of built environment on social capital and physical activity in Singapore: A structural equation modelling analysis

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ABSTRACT

Social well-being and public health have been prominent issues in developing a liveable city, especially in the unique urban context of densely populated Singapore, posing challenges for careful and efficient urban planning. As a result, it is essential to understand the association between the built environment and the social outcomes of local communities. We applied quantitative methods to assess people's perception on diverse physical features of the built environment, including availability of amenities, public spaces, and transportation options, to understand their complex interplay and collective impact on social outcomes. Data were collected from official open sources and through questionnaire surveys from three selected neighbourhoods in Singapore. Structural equation models were developed to study the interactions between various aspects of the built environment and social outcomes that include social capital and physical activity of the residents. The results show that the influence of objective measures of the built environment is not significant, but the perceived built environment aspects of inclusivity and quality have direct positive influence on social capital. Perceived built environment aspects were also found to have an indirect influence on physical activity variables of frequency and mode, with social capital being the mediator.

1. Introduction

An increasing body of research is highlighting the impact of the built environment on social outcomes, which is leading urban planners in various cities to strive for city designs that yield favourable social outcomes. The central hypothesis in this study is that the built environment provides the setting for social activities; therefore, its design influences communities' activities and social outcomes. Social capital and physical activity of the residents are among crucial outcomes in urban design: the former holds the communities together and the latter has proven to improve their health, and thereby reducing the long-term healthcare related costs for the residents. In that context, urban design has been a central subject of study to understand the impact of built environment on people's lives.

The objective of this paper is to understand the relationship between the built environment and social capital and physical activity in the Singapore context. The specific research questions addressed in this study include 1) How do the physical features of a neighbourhood affect social capital within the community? and 2) How is people's physical activity pattern influenced by the built environment? A summary of related studies is provided in Section 2, which shows that there exists a large number of studies on the influence of built environment on social capital and physical activity, but very few studies have looked at the complex interactions between the built environment, social capital and physical activity together, which is particularly relevant from the standpoint of the urban planners.

ORCID(s):

The remainder of the paper is organized as follows. The next section (Section 2) provides a summary of related works. Section 3 discusses the details of data collection and modelling methods. In Section 4, we present the results and inferences and we conclude with the summary of our findings in Section 5.

2. Literature review

2.1. Definitions of built environment, social capital and physical activity

The built environment is often defined as all the man-made physical environment that includes buildings, recreational facilities, transportation and communication systems as opposed to the natural surroundings (Kemp et al., 1997; Papas et al., 2007). Notably, Handy et al. (2002) included the human activity along with the man-made surroundings while describing the built environment. Similar definitions for the built environment are adopted by government agencies across the world. For example, the United States environmental protection agency and different Singapore government agencies describe the built environment in a very similar fashion as the man-made buildings and structures that provide the setting for their daily activities of living such as work and recreation (U.S. Environmental Protection Agency, 2023; Ministry of Education, Singapore, 2023).

The influence of the built environment on people's daily life has been studied extensively in the literature, which include studies on the influence of the built environment on social capital (Wood et al., 2008; Boessen et al., 2018; Oidjarv, 2018; Hanibuchi et al., 2012; Sun et al., 2022; Cohen et al., 2008), physical activity and health (Petrunoff et al., 2021; Handy et al., 2002; Song et al., 2020; Hou et al., 2020), travel behaviour (Susilo and Maat, 2007; Sabouri et al., 2020; Ding et al., 2017; Cervero et al., 2009) and leisure activities (Liu et al., 2020) to name a few. In this study we focus our attention on two crucial social outcomes of the built environment, namely social capital and physical activity.

Bourdieu et al. (1986) and Coleman (1988) provided some of the earliest definitions for social capital, where Bourdieu et al. (1986) explained social capital as the sum of resources accumulated by an individual or a group as a result of a durable network of social relationships and Coleman (1988) described social capital as a productive social network. Later, social capital has been described by the social attributes such as trust, norms of reciprocity, and memberships in groups that makes way for collective action (Kawachi, 1999; Putnam, 1994). Likewise, Fukuyama (2001) and Healy and Côté (2001) defined social capital as an informal norm or networks that encourage association between individuals and groups. Government authorities, such as the Singapore's Ministry for Culture, Community and Youth (MCCY) defines social capital as the social networks of trust and support, which is crucial in building a shared identity and sense of belonging (Ministry of Culture, Community and Youth, Singapore, 2022). In summary, social networks, participation in community activities, trust and reciprocity, shared norms and values, attachment and sense of belonging are some common terminologies that come across the definition of social capital.

According to the World Health Organization (WHO), physical activity is an important, modifiable behaviour for the prevention of non-communicable diseases and multiple studies have found that physical activity can reduce the risk of a large number of diseases from diabetes and cardiovascular diseases (Bassuk and Manson, 2005) to cancer (Kushi et al., 2012). Ding and Gebel (2012) conducted a review of studies on the built environment's influence on physical activity and found that a large majority of studies focus on specific modes of physical activity such as the transport-related physical activity or walking as a mode of physical activity. In the current study we look at different modes of physical activity such as walking, cycling, jogging, swimming, using gym and doing other sports as these may also be influenced by the built environment features that facilitate these activities. The government authorities in Singapore are ardently promoting a physically active lifestyle for Singapore residents. For example, the Health Promotion Board (HPB) incentivizes physical activity among residents and conducts various community physical activity programs to promote the health and wellness of residents in local communities (HPB, 2023).

2.2. Indicators for built environment, social capital and physical activity

One of the main challenges faced by researchers while studying the impact of the built environment on social outcomes is finding methods to quantify the built environment. Consequently, a wide variety of built environment measures are used in different studies (Mazumdar et al., 2018). The indicators used in measuring the built environment can be classified under the well-established 4-D principles: density, diversity, designation accessibility, and distance to transit (Cervero and Kockelman, 1997) and a brief discussion of how these indicators are measured is shown in Table 1. These indicators of the built environment can either be quantified objectively by auditing the built environment of a neighbourhood or subjectively by interviewing the people living within the neighbourhood to understand their perception about the built environment.

Like built environment, measuring social capital is also not a trivial task and a wide range of social capital indicators can be found in the literature (Mazumdar et al., 2018). Quantity of social network measured as the number of ties, quality of social network measured by the type of ties, frequency of taking part in social activities, sense of community and attachment to the neighbourhood, trust and reciprocity, etc., were found to be the most common indicators used in measuring social capital. For example, Asiamah et al. (2020) measured the social networking size as the number of people who visited a person, visited by the person or who accompanied that person in any social activity with a minimum weekly frequency, whereas Boessen et al. (2018) categorized the social networks by three types of connections that include socializing ties, core ties and kin ties. Indicators that came under the broad themes of neighbourhood ties, sense of community, participation in neighbourhood activities, neighbourhood trust and reciprocity were also used in multiple studies (Yoo and Lee, 2016; Wen and Zhang, 2009; Oidjarv, 2018). Involvement

in community organizations is another measure used in the measurement of social capital (Dean et al., 2016). A summary of indicators for social capital is shown in Table 1.

In the study conducted by Sylvia et al. (2014), various approaches for assessing physical activity were summarized. Among these approaches, questionnaires emerged as the most prevalent method for gauging physical activity, encompassing aspects such as mode, frequency, duration, and intensity. Typically the intensity of physical activity is calculated taking into consideration the frequency and duration of various modes of physical activity. Schulz et al. (2013) and Su et al. (2014) utilized the International Physical Activity Questionnaire (IPAQ) to determine the Metabolic Equivalent of Task (MET) minutes score, which serves as an indicator of activity intensity. Wen and Zhang (2009) employed exercise frequency as a measure of physical activity levels. Drawing data from the Canadian Community Health Survey (CCHS), Humphreys et al. (2014) formulated the Physical Activity Index (PAI), computed based on MET values from reported physical activities. Similar to MET, PAI also functions as a gauge of activity intensity. At the same time, the majority of studies that modelled the relationship between the built environment and physical activity considered only transportation and outdoor recreational related physical activity measured directly based on either frequency or duration of physical activity or both (Ueshima et al., 2010; Petrunoff et al., 2021; Song et al., 2020; Hou et al., 2020). The details of the physical activity indicators are presented in Table 1.

Table 1: A summary of literature review on indicators for the built environment, social capital and physical activity.

Indicator groups	Indicators	Measure	References
Built Environment (BE)			
Density	Dwelling units or floor area	Per areal unit	Cervero and Kockelman (1997); Ewing and Cervero (2010)
	Population or employment density	Per areal unit	
Diversity	Land use mixture	Entropy	Cervero and Kockelman (1997); Ewing and Cervero (2010)
	Dissimilarity index	Proportion of dissimilar land uses with a study unit	
	Activity center mixture	Entropy of commercial land-use categories computed across all activity centers in a zone	
	Commercial density	Proportion of commercial land use categories	
Design (street features)	Local road density	Per areal unit	Cervero and Kockelman (1997); Ewing and Cervero (2010)
	Density of intersections	Number of four-way intersections per square kilometers	
	Total highway miles	Length	Koohsari et al. (2016)

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Continuation of Table 1

Indicator groups	Indicators	Measure	References
	Number of residential blocks	Per areal unit	
	Mean arterial speed limits	Speed	
	Average street width	Per areal unit	
	Total length of sidewalk	Per areal unit	
	Total length of bicycle lanes	Per areal unit	
	Number of pedestrian crossings	Count	Cervero and Kockelman (1997); Ewing and Cervero (2010)
Designation accessibility	Distance to central business district	Distance	Koohsari et al. (2016)
	Distance to commercial land uses	Land uses include convenience stores, retail services, supermarkets, food centers, entertainment and recreational uses, etc	Cervero and Kockelman (1997); Ewing and Cervero (2010)
	Accessibility to job locations	Measured by gravity models, travel times from zone <i>i</i> to zone <i>j</i> (job locations)	
Distance to transit	Transport node accessibility	Average of shortest street paths from residences/workplaces within a zone to the nearest MRT stations or bus stops	Cervero and Kockelman (1997); Ewing and Cervero (2010)
	Transit route density	Number of MRT and bus routes per areal unit	
	Average distance between transit nodes	Per areal unit	
	Transit node density	Number of stations/stops per areal unit	
Social Capital (SC)			
Social networks	Social network size	Count	Asiamah et al. (2020)
	Types of social ties	Count per type of social tie	Boessen et al. (2018)
	Frequency of meeting	Categorical variable	Hanibuchi et al. (2012)
Social participation	Memberships community organizations	Binary variable	Levasseur et al. (2010); Ejiri et al. (2019); Hanibuchi et al. (2012); Dean et al. (2016)
	Frequency	Categorical variable	Mujahid et al. (2007)
	Satisfaction level	Likert scale	Koohsari et al. (2021)
	Community index	Created from responses to questions about participating in civic engagement activities and contributing to a community project	Rogers et al. (2012)
Trust and reciprocity	Level of trust	Likert scale	Hanibuchi et al. (2012)
	Trust index	Created with responses to questions about general trust and trust of neighbours and other members of communities	Rogers et al. (2012)

Continuation of Table 1

Indicator groups	Indicators	Measure	References
Attachment and sense of belonging	Reciprocity	Categorical variable Likert scale	Mujahid et al. (2007) Hanibuchi et al. (2012)
	Level of attachment	Likert scale	Hanibuchi et al. (2012); Leyden et al. (2011)
Physical Activity (PA)			
Frequency	Frequency	Categorical variable	Wen and Zhang (2009); Ueshima et al. (2010); Song et al. (2020); Hou et al. (2020); Hanibuchi et al. (2012)
Duration	Duration	Minutes	Petrunoff et al. (2021); Song et al. (2020); Hanibuchi et al. (2012)
Intensity	Metabolic Equivalent of Task (MET) minutes score	Weighted sum of minutes	Schulz et al. (2013); Su et al. (2014)
	Physical activity level	Categorical variable	Tao et al. (2021)
	Physical activity index (PAI)	Average daily energy expenditure (kcal/kg/day)	Humphreys et al. (2014)

2.3. Relationships between the built environment, social capital and physical activity

Numerous angles have been explored to study the connection between the built environment and social outcomes, and an increasing body of literature suggests that the built environment exerts an impact on social outcomes manifested as social capital and physical activity (Wood et al., 2008; Boessen et al., 2018; Hanibuchi et al., 2012; Oidjarv, 2018; Handy et al., 2002; Petrunoff et al., 2021; Sun et al., 2022; Mazumdar et al., 2018). A summary of related studies is provided in Table 2. A systematic review conducted by Mazumdar et al. (2018) scrutinized the relationship between social capital and the built environment and determined a statistically significant correlation. Many studies, including those by Wood et al. (2008); Sun et al. (2022); Oidjarv (2018), have highlighted the affirmative impact of the built environment on social capital and feelings of safety. Similarly, Oidjarv (2018) found that the walkability aspect of the built environment positively affects social capital. However, Hanibuchi et al. (2012) noted that social capital displays a more consistent association with community age and the level of urbanization than with the built environment's walkability measure among older adults in Japan. Additionally, transit accessibility and proximity to amenities and parks were discovered to positively influence social capital, as observed by Cohen et al. (2008) and Sun et al. (2022). In a study by Boessen et al. (2018), an exploration of the relationship between built environment features and personal networks revealed the importance of the built environment in shaping personal network structure, encompassing both the quantity of social connections and their geographic distribution.

Research into the association between the built environment and the physical and mental well-being of individuals is progressively gaining attention (Moore et al., 2018). Nogueira (2009) determined a robust connection between

Table 2

Summary of literature review on the relationships between built environment, social capital and physical activity.

Reference	Study location	Relationships explored	Methods	Findings
Wood et al. (2008)	Australia	BE → PNS	Linear regression	Significant, but small effect
Sun et al. (2022)	China	BE → PNS	SEM	Significant effect
Boessen et al. (2018)	US	BE → SN	Negative binomial regression	Significant effect
Hanibuchi et al. (2012)	Japan (seniors)	BE → SC	Logistic regression	Significant influence of community age; Insignificant influence of walkability
Cohen et al. (2008)	US	BE → SC	Hierarchical linear regression model	Significant influence of parks; Significant negative influence of alcohol outlets
Oidjarv (2018)	US	BE → SC	Linear regression	Inconclusive
Bhuyan and Yuen (2021)	Singapore (seniors)	BE → SC, PH, MH	Content analysis of focus group discussions	Significant effect
Mao et al. (2022)	China (seniors)	BE → SC → MH	SEM	Insignificant effect
Wang et al. (2021)	China	BE → PA	Two-way factorial ANOVA	Significant effect on duration of PA in neighbourhood
Hou et al. (2020)	Singapore (seniors)	BE → PA	Ordered probit model	Significant influence of BE on PA; Significant influence of PA on PH
Yang et al. (2019)	China (seniors)	BE → PA	Multilevel logistic regression	Significant effect of street greenery on walking time
Handy et al. (2002)	US	BE → PA	Survey of Literature	Inconclusive
Song et al. (2020)	Singapore (seniors)	BE → PA, PA → PH	Simultaneous equation model	Significant influence of perceived BE on PA; Insignificant influence of objective PA on PH
Petrunoff et al. (2021)	Singapore	BE → PA, PA → MH	Linear regression	Insignificant influence of parks access on PA; Significant influence of PA on well being
Button et al. (2013)	Canada (school children)	BE → PA, SC → PA	Multi-level regression	Significant effect, SC has more influence on PA than BE
Tang et al. (2022)	China (seniors)	BE → MH, SC → MH	SEM	Significant effect
Ueshima et al. (2010)	Japan	SC → PA	Logistic regression	Significant effect
Nogueira (2009)	Portugal	SC → PH	Logistic regression	Significant effect
Yu et al. (2015)	UK	SC → MH, SC → PH	SEM	Significant effect

BE: Built Environment, PNS: Perceived Neighbourhood Safety, SN: Social Network, SC: Social Capital, PA: Physical Activity, PH: Physical Health, MH: Mental Health, SEM: Structural Equation Modelling

social capital and self-rated health. A growing body of evidence indicates that both the built environment and social capital exert an impact on physical activity, which subsequently contributes positively to the physical and mental welfare of people. Ueshima et al. (2010) conducted a study using cross-sectional survey data from Japan to explore the association between social capital and physical activity, revealing that diminished individual-level social capital

was linked to reduced physical activity among Japanese adults. Wang et al. (2021) conducted a longitudinal study to investigate the moderation effect of the built environment density on the duration of physical activity during the COVID-19 pandemic and reported that low-density areas have a smaller decreases in physical activity during the pandemic compared to the residents of high-density neighbourhoods. Another study by Yang et al. (2019) found that street greenery has a positive influence on walking time of older adults in Hong Kong. Similarly, Kim and Miller (2019) also reported positive relationship with the distance to green infrastructure and physical activity of people in Blacksburg, Virginia. Investigating the relationship between perceived and actual park accessibility and physical activity in Singapore, Petrunoff et al. (2021) discovered a significant link between the duration of park-based physical activity and well-being. Similarly, Handy et al. (2002) investigated the effect of the built environment on active mobility, such as walking and cycling, as a form of physical activity and reported that physical and psychological barriers to walking and cycling can be overcome by increasing the pedestrian orientation of the built environment through mixed-use development, street connectivity, and good design.

According to the findings of Song et al. (2020), enhancing the availability of destinations like parks, open spaces, playgrounds, and walkability features can encourage outdoor physical activities among older residents in Singapore, consequently contributing to their overall health. Analyzing neighbourhood-level data from Singapore, Hou et al. (2020) examined how older adults' perceptions and objective aspects of the built environment are related to their daily travel behaviours. The results indicate that the perceived accessibility to recreational facilities positively impacts the frequency of older adults' walking trips, whereas objective measures of the built environment do not significantly affect their travel activities. Meanwhile, Bhuyan and Yuen (2021) utilized content analysis of focus group discussions in Singapore to explore how older adults perceive the connection between the neighbourhood built environment and their physical, social, and mental well-being. The study revealed that older adults' physical health is influenced by safety and pedestrian-friendly zones, social health is tied to safety and amenities, and mental health is associated with visual aesthetics and wayfinding.

The literature review shows that most of the existing studies considered either relationship between the built environment and social capital or the built environment and physical activity. Few studies considered the interactions between built environment, social capital and physical activity together. One study that considered these three together is Button et al. (2013), in which they studied the relationship between the built environment and social capital of schools with physical activity of students in Canada and found that social capital is more important than the built environment in increasing the physical activity of students. In Singapore specifically, majority of the studies considered the influence of the built environment on physical activity of older adults only (Bhuyan and Yuen, 2021; Hou et al., 2020; Song et al., 2020). To date, little has been known about the complex interactions between the built environment, social capital and physical activity for the general population and in a wider built environment context. The current study tries to

fill this research gap by studying the influence of the built environment on social capital and physical activity together for the general population in three neighbourhoods in Singapore by considering the possible interactions between these variables. Our study can provide valuable insights for policy makers and urban planners, who are striving for liveable and sustainable cities by designing spaces that provide a better sense of community and satisfaction among the residents, which also provide opportunities for physically active lifestyle to improve the overall health of the residents.

3. Data and Methods

3.1. Study sites selection

In Singapore, the land use plans are set, reviewed and updated periodically by the Urban Redevelopment Authority of Singapore (URA). As per the URA master plan 2019, the country consists of 55 planning areas, each of which has a population of about 150,000 and contains centres to serve its residents. The planning areas are further divided into 323 sub-zones. In this study, we decided to select three planning areas with diverse physical features of the built environment so as to maximize their representativeness of a variety of land use, morphology features and urban designs in Singapore. Using several indicators of built environment features, we examined and quantified all planning areas in Singapore accordingly. We focused on two main aspects, which are land-use pattern and amenity availability in each planning area. First, we performed a clustering of the planning areas based on their land-use composition (Huynh, 2022) to identify different groups of planning areas. Second, we clustered the planning areas based on the different amenity types available therein. After that, we combined the two grouping schemes to identify the areas with the most diverse physical characteristics. As Singapore is a country with heavy focus on transit-oriented development, public transport accessibility was also additionally considered and aided the site selection process.

The three selected planning areas were Bukit Batok, Sembawang and Toa Payoh as shown in Figure 1 (in the subsequent text, we will also refer to them as neighbourhoods). Toa Payoh is one of the oldest housing estates in Singapore, which started developing in 1960s and is a mature town now. These estates were developed in such a way that several neighbourhoods are clustered around a town centre, which acts as a principal location for the entertainment and shopping needs of residents. Bukit Batok is a middle-aged town where the residential estates were developed in 1980s, which has been developed into a self-sustaining town with work spaces, shopping centers and recreational areas, making it a connected living space for the residents. Sembawang is a relatively young town, with a maritime past, where the British naval base was located. Sembawang town hosts a few parks, and new generation neighbourhood centres (Housing and Development Board, Singapore, 2023). In terms of land-use pattern (see panels 1-3 in Figure 1) and amenity type, Bukit Batok has high coverage of green space, and its amenities are typical of a younger town with modern services (e.g. educational institutions or supermarkets). Similarly, Sembawang also has amenities of younger type, but it has high coverage of industrial land-use. On the other hand, Toa Payoh, has high coverage of land used

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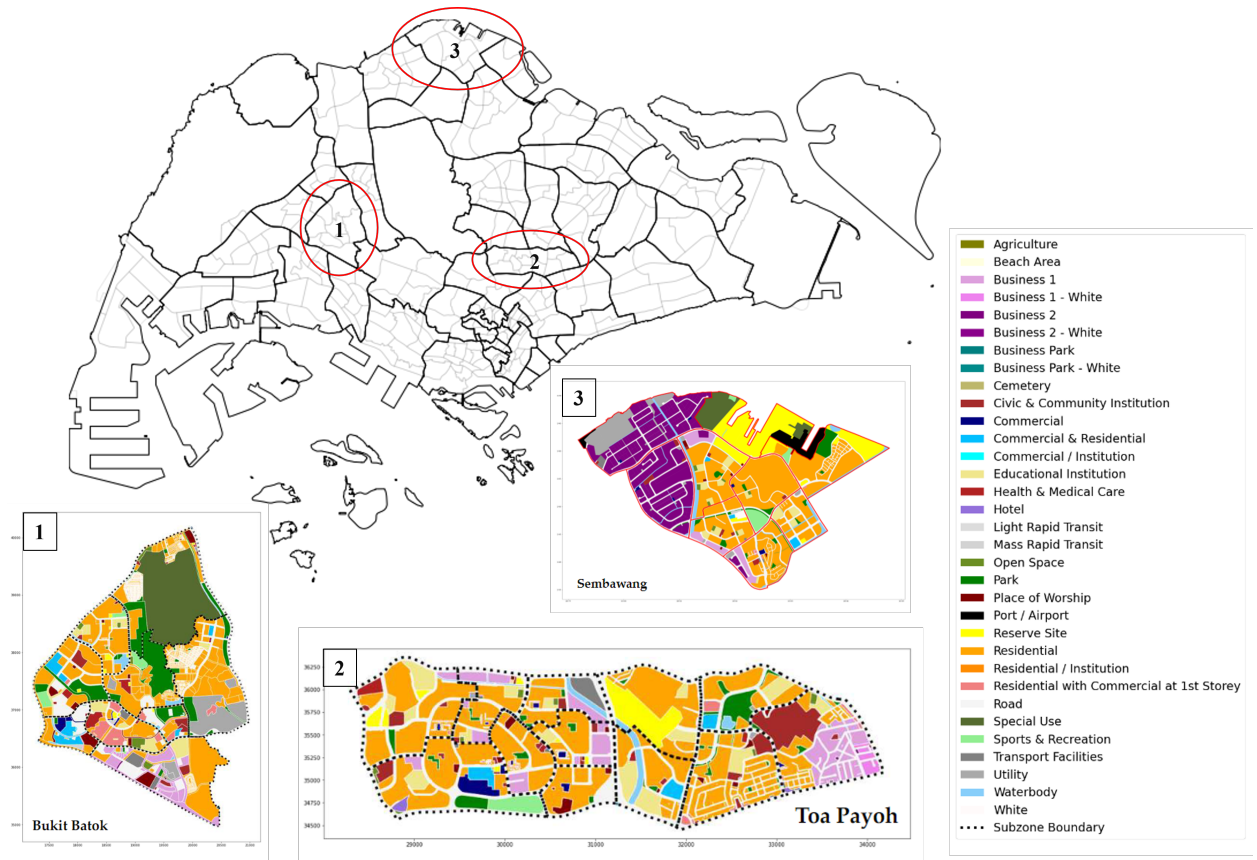


Figure 1: Singapore's planning areas, sub-zones and the three selected neighbourhoods together with their land-use pattern.

for residential purpose and its amenities are of older type with traditional characteristics (e.g. hawker centres or wet markets). In terms of quality of public transport, the three selected towns also exhibit marked differences with Bukit Batok having average, Sembawang having low, and Toa Payoh having good public transport accessibility (Yadav et al., 2023). Thus our study area selection criteria ensured representative neighbourhoods for entire Singapore to bring about external validity of the study beyond the selected neighbourhoods.

3.2. Survey Design

The questionnaire survey was designed to collect data on people's perception on the built environment, social capital, physical activity and health indicators along with basic socio-demographic variables. The indicators adopted in this study were mainly derived from the literature reviewed described earlier, with their relevance for the Singapore context being a factor for inclusion. Specifically, we shortlisted 11 indicators to measure the perceived built environment, where the participants were asked to rate on a five-point Likert scale from very unhappy (1) to very happy (5). The details of these indicators are shown in Table 3. Similarly, we selected 11 indicators to measure the social capital based on relevant studies. The ratings range from completely disagree (1) to completely agree (5).

The details of the indicators used are also presented in Table 3. The table also presents the sub-categorization of the variables and the corresponding indicators used in the model exploration.

In the current study, we focus on measuring only two aspects of physical activity, which are the mode and frequency of physical activity. These two aspects were chosen as they are more likely to be influential on the relationship between physical activity, the built environment, and social capital (Ueshima et al., 2010; Mao et al., 2022; Song et al., 2020; Hou et al., 2020). To measure the mode of doing physical activity, we inquired information on respondents' different forms of physical activity that include walking, jogging, cycling, swimming, doing sports, use of gyms, etc. As for frequency (e.g. the number of times per week or month), we asked respondents about their frequency of doing a wide range of physical activities as presented in Table 3.

Table 3

Details of indicators used to measure the perceived built environment, social capital and physical activity.

Latent variable or sub-group	Indicators
Built environment¹	
Built environment amenities	BE1: Availability of basic amenities and services BE2: Connection to public transport
Built environment inclusivity	BE3: Family-friendly facilities BE4: Walkability of pedestrian facilities BE5: Wheelchairs/strollers accessibility
Built environment visual beauty	BE6: Availability of green space BE7: Visual beauty of surroundings
Built environment quality	BE8: Overall safety and security level BE9: Air quality BE10: Cleanliness of public space BE11: Noise level
Social capital²	
Social interaction	SC1: Knowing neighbours very well SC2: Easy to get help from neighbours SC3: Space and facilities for social interaction SC4: Enjoy meeting neighbours in public areas SC5: A lot of activities and events
Social trust	SC6: Residents can be trusted SC7: Residents share the same values SC8: Residents getting along with each other
Neighbourhood attachment	SC9: Feeling attached to the neighbourhood SC10: Intention to stay for long term SC11: Unique identity of the neighbourhood
Physical activity	
Frequency of physical activity ³	PAF1: Typical frequency of playing sports (e.g. football, basketball, tennis) PAF2: Typical frequency of working out in gym PAF3: Typical frequency of swimming PAF4: Typical frequency of jogging
Mode of physical activity ⁴	PAM1: Used swimming pool in the last month PAM2: Used Gym in the last month PAM3: Total number of facilities used for physical activities in the last month

¹ Indicators rated on 5-point Likert scale - very unhappy to very happy.

² Indicators rated on 5-point Likert scale - completely disagree to completely agree.

³ 5 categories: everyday, a few times per week, once or twice per month, once in a while, never.

⁴ Use of specific facilities and total number of facilities (e.g. neighbourhood fitness corner, gym, walking/jogging paths, bike paths, swimming pools) used in the last month.

On top of collecting information on the important indicators for the built environment, social capital and physical activity, we included some basic questions on their health pertaining to their self-rated health level, height and weight information to calculate the Body Mass Index (BMI) and presence of common lifestyle diseases such as high blood pressure, diabetes, high cholesterol, etc. We also collected information on the socio-demographic variables such as gender, age, ethnicity, education, employment status, income, housing type, number of household members, number of children in the household and their main mode of transport.

3.3. Sampling and data collection

In the study, we adopted a stratified random sampling with a total target sample of 1,000 respondents from the three neighbourhoods. The target sample from each neighbourhood was then calculated in proportion to the population residing in these neighbourhoods, as reported in census 2019. Within the neighbourhoods, stratifications were applied based on demographic variables of age group, gender and ethnicity. For age group, we considered 3 broad groups of 21-39, 40-59 and 60 and above. For ethnicity, we have 3 groups representing Chinese, Malay, and Indian and Others as per the government's classification of race in Singapore. We randomly selected the participants in the survey by intercepting them on the respective neighbourhoods, where the participants were recruited at several locations such as town centres, shopping malls, MRT stations and parks to ensure the representativeness of the sample. Our inclusion criteria ensured that only respondents with home location in one of the three neighbourhoods were qualified for the survey. Thus, the adopted sampling strategy included measures to avoid sampling bias to ensure internal validity. On top of the survey data, which provided information on perceived built environment features, we also collected data on objective built environment features that were available in the public data sources. This data was collected primarily from OneMap API (OneMap API, 2023), which is a detailed Singapore map maintained by the Singapore Land Authority (SLA), with information contribution from other government agencies. Using the OneMap API, we collected data on various amenities, parks, cycling network, fitness corners, etc.

3.4. Conceptual model and model selection process

Structural Equation Modelling (SEM) is a multivariate technique used in a variety of fields including natural sciences, social sciences, health sciences to test the direct and indirect causal relationship between the variables of interest. SEM is a combination of different multi-variate statistical techniques that include multiple regression analysis, factor analysis and path analysis. Factor analysis was originally applied in psychology to study the latent traits such as attitude and satisfaction. On the other hand, path analysis originated in biometric studies to find the causal relationship among variables using a path diagram. In this study, we adopted SEM approach following related studies (Tang et al., 2022; Mao et al., 2022; Ikeda et al., 2019; Yu et al., 2015) due to the latent nature of the variables involved and the direct and indirect relationships between multiple variables being tested.

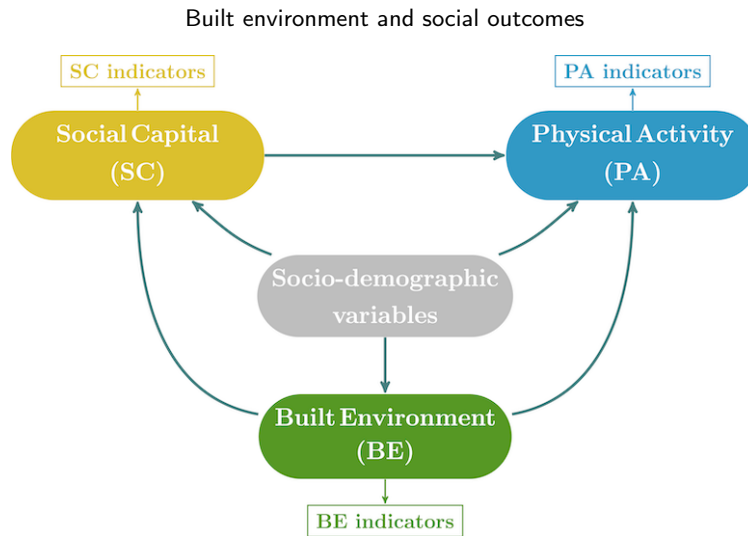


Figure 2: Conceptual Model

The basic conceptual model we considered is shown in Figure 2. The model consists of three latent variables which cannot be directly measured. As a result, multiple measurement variables or observable items are needed to measure each of these variables. On top of that, the socio-demographic variables can have an influence on the social capital, physical activity and the perceived built environment latent variables, which are often taken as control variables (Yu et al., 2015; Hanibuchi et al., 2012; Song et al., 2020; Button et al., 2013). Based on the findings from literature (see Table 2), the built environment is likely to influence social capital and physical activity. Similarly, the social capital is likely to influence the physical activity. In the model exploration stage, all the variables available from the surveys and the objective measures of the built environment were considered. Structural relationships were tested between the objective measures of the built environment and the built environment latent variable. Similarly, structural relationships were tested between the socio-demographic variables collected in the surveys and the social capital, physical activity and perceived built environment latent variables. The measurement model for the built environment latent variable was constructed using the perceived built environment indicators from the survey. Likewise, measurement models for social capital and physical activity latent variables were developed based on the respective indicators collected through the surveys.

The model selection was based on a combination of data-driven and theory-driven approaches. All the indicators available from the survey were first grouped into the main category of latent variables which is built environment, social capital and physical activity. The measurement model for the latent variables was then established using a data driven approach, where we tested all combinations of indicators under one group and shortlisted the combination of indicators that resulted in acceptable levels of internal consistency as indicated by Cronbach's α greater than 0.7. The shortlisted groups of indicators were named based on what aspect of the latent variable is explained by the indicator groups. Thus the main latent variables were classified into more specific latent constructs within the category. The resulting

sub-groups of the built environment include natural environment, inclusivity of the built environment, amenities and the quality of the built environment. Social capital was further categorized into specific variables such as social trust, attachment and social interactions. The physical activity variable was categorized into mode and frequency of physical activity. The indicators used for the sub-categories are shown in Table 3.

We used *semopy* (Igolkina and Meshcheryakov, 2020), the python package for structural equation modelling at the data driven model exploration stage due to its automation capability and SPSS Amos software at the fine tuning stage of the selected models.

4. Results and discussions

4.1. Descriptive statistics

The data collection was carried out by a market research company using the methods described earlier. In total, 1,000 completed questionnaires were collected, with 418 samples from Bukit Batok, 340 samples from Toa Payoh, and 242 samples from Sembawang. As mentioned earlier, the sample size from each neighbourhood was proportional to the population residing therein, ensuring representative sampling by age group, gender and ethnicity within each area.

For identifying outliers in the data, the normality of the data was first assessed using skewness $< \pm 2$ and kurtosis statistic $< \pm 10$ criteria. All the continuous variables included in the model except PAF1 (typical frequency of playing sports) satisfied this criteria. For the PAF1 (typical frequency of playing sports) variable, although the skewness was less than -2, it was well within the extended limit of -3 and kurtosis was less than 10. Since non-normality did not arise in our data, we retained about 32 outliers as suggested by the Mahanobis Distance (Collier, 2020). Results of normality assessment can be found in Appendix A.

Table 4 shows the socio-demographic characteristics of the respondents from these three neighbourhoods. For categorical variables, the count in each category and percentage for the respective category are shown. In case of continuous variables, the mean and standard deviation are presented in the table. Average number of children in household were found to be lowest in Toa Payoh, followed by Bukit Batok and Sembawang. This was expected due to Toa Payoh being an older estate where the proportion of older age groups is higher. Sembawang has a relatively lower population of seniors. This effect on demographics is also reflected on the other variables such as education, income and employment.

The results of the built environment and social capital indicator ratings for the three different neighbourhoods are shown in the radar charts in Figure 3. Sembawang residents gave the highest average rating for all built environment indicators considered, except for BE2 (connection to public transport). Being the newest estate among the three, Sembawang has a higher chance of having the more advanced built environment features, which is also reflected in the perception of the people residing there. Next higher ratings for built environment features were provided by Toa Payoh

Table 4
Socio-demographic characteristics of the study participants.

Variables	Total		Bukit Batok		Sembawang		Toa Payoh	
	Count	%	Count	%	Count	%	Count	%
Categorical Variables								
Age								
21-39	353	0.35	153	0.37	96	0.40	104	0.31
40-59	382	0.38	158	0.38	101	0.42	123	0.36
60 and above	265	0.27	107	0.26	45	0.19	113	0.33
Gender								
Male	483	0.48	205	0.49	118	0.49	160	0.47
Female	517	0.52	213	0.51	124	0.51	180	0.53
Ethnicity								
Chinese	764	0.76	308	0.74	177	0.73	279	0.82
Malay	116	0.12	58	0.14	32	0.13	26	0.08
Indian	110	0.11	46	0.11	30	0.12	34	0.10
Others	10	0.01	6	0.01	3	0.01	1	0.00
Education								
Lower – Primary, secondary	564	0.57	227	0.54	131	0.54	206	0.62
Middle – Diploma	251	0.25	104	0.25	68	0.28	79	0.24
High – University graduate	175	0.18	87	0.21	42	0.17	46	0.14
Income								
Below S\$50,000/year	787	0.82	322	0.81	178	0.78	287	0.88
S\$50,001–S\$100,000/year	138	0.14	63	0.16	45	0.20	30	0.09
Above S\$100,000/year	30	0.03	14	0.04	6	0.03	10	0.03
Employment								
Employed	709	0.71	307	0.73	184	0.76	218	0.64
Unemployed	253	0.25	101	0.24	44	0.18	108	0.32
Others	38	0.04	10	0.02	14	0.06	14	0.04
Housing type								
Housing Development Board 1-3 room flat	371	0.37	145	0.35	62	0.26	164	0.48
Housing Development Board 4-room flat	353	0.35	152	0.36	108	0.45	93	0.27
Housing Development Board 5-room and larger flat	160	0.16	70	0.17	39	0.16	51	0.15
Private apartment, Landed	116	0.12	51	0.12	33	0.14	32	0.09
Housing Tenure								
Rent	93	0.09	33	0.08	32	0.13	28	0.08
Self-owned	684	0.68	300	0.72	157	0.65	227	0.67
Owned by my family	218	0.22	81	0.19	52	0.21	85	0.25
Others	5	0.01	4	0.01	1	0.00	0	0.00
Continuous Variables								
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household size	3.53	1.29	3.5	1.3	3.7	1.27	3.44	1.28
No. of children	0.41	0.76	0.45	0.82	0.5	0.8	0.3	0.64

residents and lowest ratings were from Bukit Batok residents. One built environment indicator that the residents of all three neighbourhood consistently gave good rating was BE1 (availability of basic amenities and services, e.g. ATMs, clinics, supermarkets, food courts), indicating the compact neighbourhoods with accessibility to basic amenities, which is a common feature that can be observed island-wide in Singapore.

As shown in Figure 3(b), the variability in the average rating for social capital indicators among residents of the three neighbourhoods were lesser compared to the built environment indicators. Also, the average ratings for social capital indicators were lesser than that of built environment indicators, indicating that the residents are more satisfied

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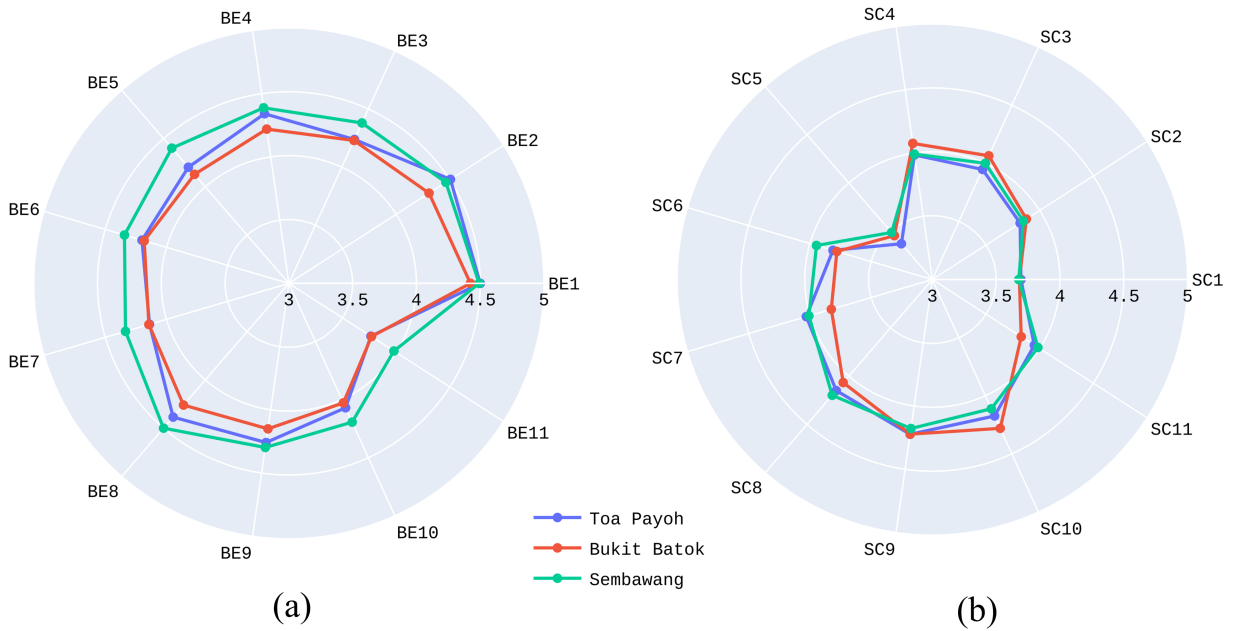


Figure 3: Average rating for (a) built environment and (b) social capital indicators. The details of the indicators can be found in Table 3.

with the physical features than the social aspects in these neighbourhoods. Among the three neighbourhoods, either Sembawang or Bukit Batok residents provided highest average rating on most indicators with Toa Payoh residents giving equally good rating for some indicators. Sembawang residents had slightly higher ratings for SC6 (residents of my neighbourhood can be trusted), whereas Bukit Batok residents rated higher for SC3 (space and facilities for social interaction), SC4 (enjoy meeting neighbours in public areas) and SC10 (intention to stay long term). Following the survey, we also conducted in-depth interviews with selected 30 respondents of the survey, with 10 respondents from each of the three neighbourhoods. The in-depth interviews provided us with more insights into the survey responses and our interpretations are also based on that. The details of the in-depth interviews will be reported elsewhere.

4.2. Factor analysis results

Following the basic summary statistics, Confirmatory Factor Analysis (CFA) was conducted to establish the relationship between the measurement items and the latent constructs. After the measurement models were established by the CFA, the relationship between the latent variables were explored using SEM. The relationship between the latent variables were examined as sub-groups and as bigger groups. The inclusion of more than four latent variables in one structural equation model resulted in poor overall model fit, potentially due to the smaller sample size. Hence, we limited the number of latent variables to be considered in one model to four and explored various combinations of

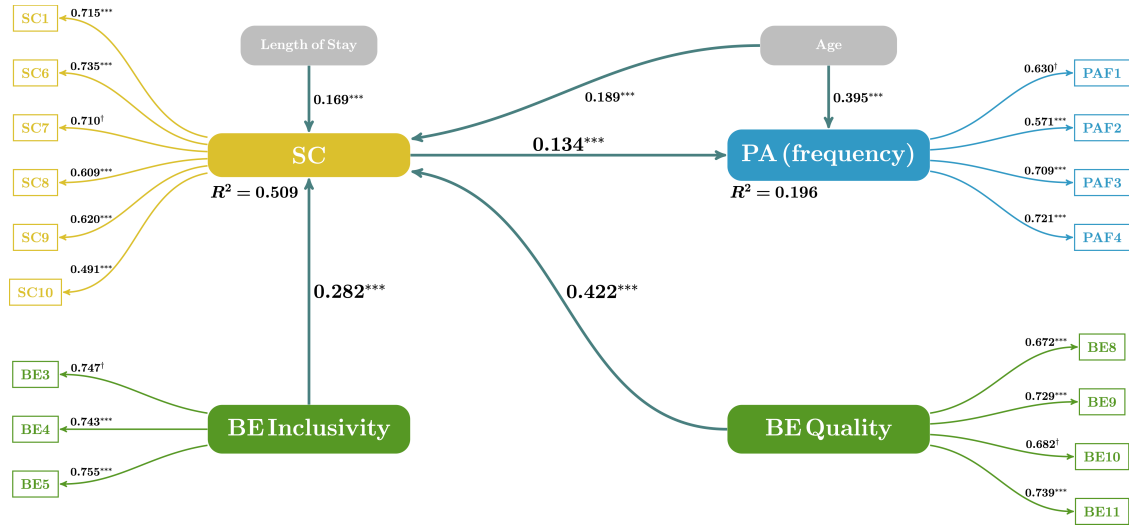
possible relationships considering both the bigger groups or sub-groups of latent variables in the model, keeping the conceptual model as a guideline for the analysis.

Structural relationships between the objective measures of the built environment, collected through secondary data sources and the perceived built environment measures collected in the surveys were also explored. In order to do this, we first normalized the objective and perceived built environment variables to get rid of the differences in the scale between them. Following this, we estimated models with different combinations of perceived and objective built environment variables in the model and it was revealed that the latent variable of built environment measured by the perceived built environment indicators does not have statistically significant relationships with the objective measures of the built environment and hence the objective measures were excluded from the final models.

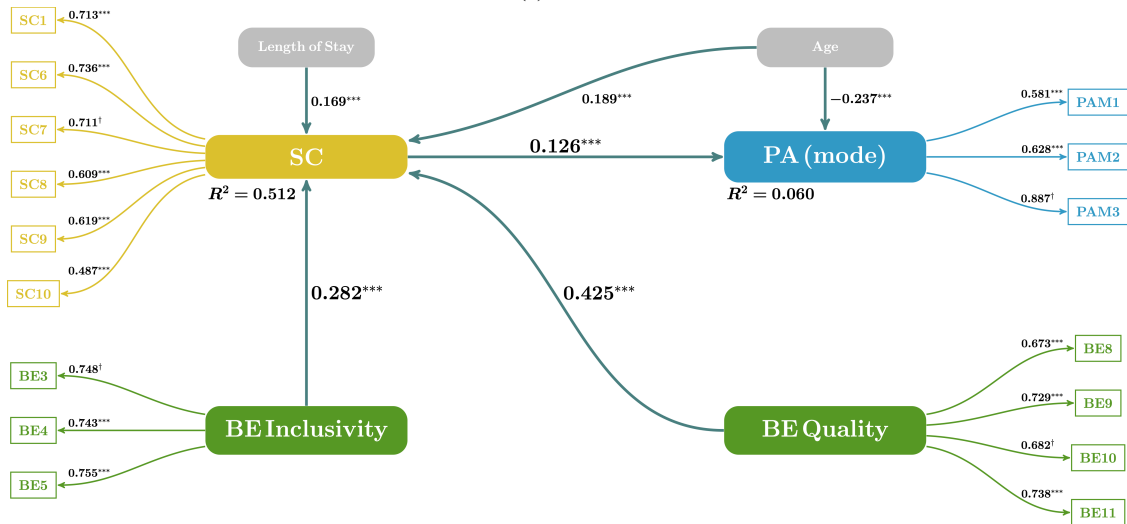
Likewise, the structural relationship between the socio-demographic variables and latent variables were explored. At the end of the model exploration stage, only four relationships were found to be statistically significant, which were between the length of stay and age with social capital and age with the mode and frequency of physical activity. Two models were selected at the end of the model exploration stage based on the goodness-of-fit measures and the statistical significance of the relationships tested within the model. Results from the selected models are shown in Table 5 and in Figure 4. Inclusion of additional co-variances in the model was guided by the modification indices, which is an estimate of the amount by which the chi-square value would be reduced if a single parameter restriction were to be removed from the model. The estimates of modification indices and estimates of additional co-variances from the selected two models are shown in Appendix B and Appendix C respectively.

The internal consistency of the measurement models in confirmatory factor analysis can be evaluated using the Cronbach's α and composite reliability, both of which are shown in Table 5. Cronbach's α values for all the measurement models are greater than 0.7, which is considered as the acceptable level of internal consistency (Hair et al., 2010). The composite reliability values for social capital, the quality and inclusivity of the built environment, and the mode of physical activity all have values more than 0.6, which is the acceptable limit in exploratory research (Hair et al., 2010). The frequency of physical activity has a slightly lower composite reliability value than 0.6. The standardized loadings of the SEM models are shown in Table 5 and Figure 4. The relationships are statistically significant in the CFA model. This indicates that the latent variables can be measured using the indicators used in the model, and thereby confirming the validity of the model. The goodness-of-fit measures of the models were evaluated using the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI). Both CFI and TLI have values above 0.9, which is considered as acceptable levels for these measures. Also, the Root Mean Square Error Approximation (RMSEA) was below the recommended level of 0.05 (Schermelele-Engel et al., 2003).

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(a) Model 1



(b) Model 2

Figure 4: The selected structural equation models - (a) Model 1, including the frequency of physical activity and (b) Model 2, including the mode of physical activity. *** $p < 0.001$, †fixed loading.

4.3. Path analysis results

In this section, we discuss the structural relationships between the latent variables and its inferences. As shown in Figure 4, the relationships between the latent variables are statistically significant in both models. A summary of the structural relationships between the latent variables are also shown in Table 6. The table indicates direct effects, which are the standardized loadings shown in the path diagrams, indirect or mediating effects which are calculated as the product of standardized loadings in the indirect paths between the structural variables in the path diagrams. The total effect is the sum of the direct and indirect effects, if both are present in the model. Figure 4 also shows the R^2 values for the dependent variables in the model, which show the total explained variance in the corresponding regression

Table 5

Results from the two selected models. Measurement items, their reliability expressed as Cronbach's α (CA) and composite reliability (CR), factor loadings, and goodness-of-fit measures are shown in the table.

Constructs and their respective items	Model 1	Model 2
	Factor loadings	Factor loadings
Inclusivity of the built environment (BE inclusivity, CA = 0.79, CR = 0.68)		
BE3: Family-friendly facilities (e.g. childcare centres and playgrounds)	0.747	0.748
BE4: Walkability of pedestrian facilities	0.743	0.743
BE5: Wheelchairs / strollers accessibility	0.755	0.755
Quality of the built environment (BE quality, CA = 0.80, CR = 0.66)		
BE8: Overall safety and security level	0.672	0.673
BE9: Air quality	0.729	0.729
BE10: Cleanliness of public space	0.682	0.682
BE11: Noise level	0.739	0.738
Social capital (SC, CA = 0.82, CR = 0.65)		
SC1: I know my neighbours very well	0.715	0.713
SC6: Residents of my neighbourhood can be trusted.	0.735	0.736
SC7: Residents of my neighbourhood share the same values.	0.710	0.711
SC8: Residents of my neighbourhood get along with each other.	0.609	0.609
SC9: I feel attached to the area I live in	0.620	0.619
SC10: I intend to stay for long term in the area I live in.	0.491	0.487
Socio-demographic variables influencing social capital		
Length of stay	0.169	0.169
Age	0.189	0.189
Frequency of physical activity (PA frequency, CA = 0.75, CR = 0.57)		
PAF1: Frequency of doing sports	0.630	-
PAF2: Frequency of using gym	0.571	-
PAF3: Frequency of swimming	0.709	-
PAF4: Frequency of jogging	0.721	-
Socio-demographic variables influencing frequency of physical activity		
Age	0.395	-
Mode of physical activity (PA mode, CA = 0.74, CR = 0.61)		
PAM1: Use of swimming pool in last month	-	0.581
PAM2: Use of gym facility in last month	-	0.628
PAM3: Number of facilities used in last month	-	0.887
Socio-demographic variables influencing mode of physical activity		
Age	-	-0.237
Model goodness-of-fit measures		
	Values	Values
Chi square (Degree of Freedom)	349.993(140)	385.174(123)
Comparative Fit Index (CFI)	0.965	0.955
Tucker-Lewis Index (TLI)	0.958	0.944
Root Mean Square Error Approximation (RMSEA)	0.039	0.046

model. As shown in the figure, the models are able to explain slightly above 50% of variance in the social capital. On the other hand, the Model 1 is able to explain about 20% of variance in physical activity frequency and Model 2 about 6% variance in physical activity mode, indicating that there are considerable other effects influencing physical activity, which are not included in the current model.

Consistent with multiple studies from the literature (Cohen et al., 2008; Hanibuchi et al., 2012; Boessen et al., 2018), the results from both models show that built environment's impact on social capital is significant. More specifically,

Table 6

Structural relationships between latent variables in the model.

Structural relationship	Direct effect	Indirect effect	Total effect
Model 1			
BE inclusivity → Social capital	0.282	-	0.282
BE inclusivity → Frequency of physical activity	-	0.038	0.038
BE Quality → Social capital	0.422	-	0.422
BE Quality → Frequency of physical activity	-	0.057	0.057
Social capital → Frequency of physical activity	0.134	-	0.134
Model 2			
BE inclusivity → Social capital	0.282	-	0.282
BE inclusivity → Mode of physical activity	-	0.036	0.036
BE Quality → Social capital	0.425	-	0.425
BE Quality → Mode of physical activity	-	0.054	0.054
Social capital → Mode of physical activity	0.126	-	0.126

our study shows that built environment features such as inclusivity and quality have positive and statistically significant relationship with social capital, with built environment quality having higher loadings compared to built environment inclusivity, showing the importance of built environment quality on the social capital. This implies that ensuring the quality of physical spaces by maintaining cleanliness, safety and without air and noise pollution is important in deriving positive social outcomes. Similarly, neighbourhood design should consider inclusivity by considering family and pedestrian friendliness to encourage positive social outcomes among the residents. Although not exact, but similar finding to some extent is reported by Hanibuchi et al. (2012), where they reported that community age, which may dictate the quality of built environment features, has more influence on social capital compared to walkability, which is similar to the inclusivity latent variable in the current study.

After controlling for the demographic variables, the direct effects of built environment quality and inclusivity on physical activity variables of frequency and mode were found to be not statistically significant. Despite relatively small loadings, the built environment was found to have a statistically significant indirect effect with the physical activity variables of frequency and mode, with social capital being the mediator between the built environment and physical activity variables. Previous studies on built environment influence on physical activity in Singapore reported positive and significant effect (Song et al., 2020; Hou et al., 2020). But the measurement model for physical activity used in these studies only measured the transportation and recreational outdoor physical activity, since these studies were focused on older adults. As our study uses more detailed measurement model for physical activity, we are able to derive more insightful information on these relationships.

In a similar way, we also found that social capital has a small, but positive and significant influence on the frequency and mode of physical activity. The frequency of physical activity is positively influenced by social capital and hence can be increased by promoting social capital. Between the frequency and mode of physical activity, social capital has more influence on the frequency than the mode as indicated by the loadings on the path diagrams. Earlier studies also

reported positive and significant relationship of social capital with physical activity and health (Ueshima et al., 2010; Yu et al., 2015; Mao et al., 2022; Tang et al., 2022; Nogueira, 2009), but we are not able to directly compare the results due to the difference in the measurement models used.

We also tested the relationship between the socio-demographic variables and the latent variables in the model. Statistically significant relationships were only observed between the length of stay in the neighbourhood and age of a person with the social capital latent variable, and age with the mode and frequency of physical activity. Both length of stay and age of a person had positive relationship with the social capital, which was expected. Age was found to have a positive relationship with the frequency of physical activity and a negative relationship with the mode of physical activity. This shows that older people are involved in more frequent physical activity, but their mode of physical activity is less likely to involve specific facilities like gym and swimming pool and use of multiple facilities. Likewise, in the model exploration stage we also considered qualitative measures of the built environment, which were not found to be statistically significant in explaining the built environment latent variable, in agreement with the findings of Hou et al. (2020) for the built environment influence of older adults' walking trips in Singapore.

5. Conclusions

In this study, we collected data from three neighbourhoods in Singapore on the perceived built environment features, social capital and physical activity indicators along with socio-demographic variables using surveys. We also collected information on objective measures of built environment from secondary sources of data. Using structural equation modelling, the relationship of the built environment with social capital and physical activity variables was explored. Through this study we found that there is no statistically significant relationship between the objective and perceived built environment variables. The results from our study also show that the perceived built environment has a statistically significant and positive relationship with social capital. Although no significant direct relationships were observed between perceived built environment and physical activity variables, the perceived built environment was found to have positive indirect relationships with the frequency and mode of physical activity, with social capital being the mediating variable. The socio-demographic variables of age and length of stay were significant control variables for social capital. Likewise, age was a significant control variable for physical activity mode and frequency.

The World Health Organization defines a healthy city as one that constantly designs and upgrades its physical and social surroundings and expands the community resources to help its residents to support each other in their day-to-day life and to help in reaching their maximum potential (WHO, 2020). Urban planners are striving to provide such inclusive, livable and healthy cities, by carefully designing the urban environment. Development of social capital and healthy living habits of urban dwellers are key aspects of any healthy city. We believe our study provides useful insights for urban planners into how the built environment factors can positively influence the social capital and physical activity

variables, thereby helping them to design an urban setting that would result in the desired social outcomes. Based on the perceived built environment ratings, the findings from the study suggest that the design features of Sembawang neighbourhood can be emulated while developing new neighbourhoods and those of Bukit Batok (low rating for inclusivity and quality) should be avoided. Also, neighbourhood design should consider inclusivity by considering family and pedestrian friendliness and ensuring the quality of physical spaces by maintaining cleanliness, safety and without air and noise pollution to achieve positive social outcomes.

This study offers a nuanced understanding of the intricate relationship between the built environment and social outcomes in Singapore. The findings could help inform evidence-based urban planning for adaptive and resilient communities, unraveling complex dynamics and promoting sustainable, inclusive environments that enhance social capital and active lifestyles. The current study had constraints on incorporation of larger number of latent constructs in the model due to the limited sample size, owing to the budget constraints. However, in future research, as a larger sample becomes available, it will be possible to investigate the connections among additional latent constructs all at once within a single model. This approach will enhance the understanding of their intricate interactions and unveil deeper insights.

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A. Assessment of normality**Table A1**

Results of assessment of normality for continuous variables in the model.

Variable	skew	kurtosis
Age	0.153	-0.938
Length of stay	-1.778	1.946
BE3: Family-friendly facilities	-0.697	0.574
BE4: Walkability of pedestrian facilities	-0.811	1.400
BE5: Wheelchairs / strollers accessibility	-0.772	0.706
BE8: Overall safety and security level	-0.754	0.406
BE9: Air quality	-1.006	1.933
BE10: Cleanliness of public space	-1.029	1.375
BE11: Noise level	-0.726	0.094
SC1: Knowing neighbours very well	-0.572	-0.280
SC6: Residents can be trusted	-0.239	0.213
SC7: Residents share the same values	-0.411	0.252
SC8: Residents getting along with each other	-0.615	1.913
SC9: Feeling attached to the neighbourhood	-0.346	0.017
SC10: Intention to stay for long term	-1.060	1.121
PAF1: Typical frequency of playing sports	-2.678	6.432
PAF2: Typical frequency of working out in gym	-1.852	1.958
PAF3: Typical frequency of swimming	-1.913	2.867
PAF4: Typical frequency of jogging	-1.234	0.079
PAM3: Number of facilities used in last month	0.741	0.893

B. Modification Indices

Table B1

Modification Indices (MI) values above 10 are reported in the table with Expected Percentage Change (EPC) in Chi-square values.

Co-variances/Regression	MI	EPC
Model 1		
Error in BE11: Noise level ↔ BE inclusivity	19.018	-0.047
Error in SC7: Residents share the same values ↔ BE inclusivity	16.035	0.033
Error in SC7: Residents share the same values ↔ Error in BE8: Overall safety and security level	11.972	-0.032
Error in SC1: Knowing neighbours very well ↔ Length of stay	14.303	0.124
SC1: Knowing neighbours very well ← BE Quality	12.324	-0.160
SC1: Knowing neighbours very well ← BE inclusivity	13.517	-0.186
Model 2		
Error in PAM1: Used swimming pool in the last month ↔ BE inclusivity	25.602	-0.020
Error in PAM2: Used gym in the last month ↔ Error in social capital	25.91	-0.021
Error in PAM3: Total number of facilities used in the last month ↔ BE inclusivity	25.277	0.051
Error in PAM3: Total number of facilities used in the last month ↔ Error in social capital	10.613	0.032
Error in BE11: Noise level ↔ BE inclusivity	18.918	-0.047
Error in SC7: Residents share the same values ↔ BE inclusivity	15.911	0.033
Error in SC7: Residents share the same values ↔ Error in BE8: Overall safety and security level	12.483	-0.033
Error in SC1: Knowing neighbours very well ↔ Length of stay	14.524	0.126
QPAM1: Used swimming pool in the last month ← BE inclusivity	26.141	-0.092
PAM2: Used gym in the last month ← Social capital	10.461	-0.042
PAM3: Total number of facilities used in the last month ← BE quality	10.4	0.137
PAM3: Total number of facilities used in the last month ← BE inclusivity	28.238	0.250
PAM3: Total number of facilities used in the last month ← Social capital	13.612	0.112
SC1: Knowing neighbours very well ← BE Quality	12.363	-0.161
SC1: Knowing neighbours very well ← BE inclusivity	13.441	-0.186

C. Additional co-variances

Table C1

Estimates of additional co-variances in the selected models.

Co-variances	Estimate	p-value
Model 1		
BE inclusivity ↔ BE quality	0.199	< 0.001
Length of stay ↔ BE quality	0.046	0.101
Age ↔ BE quality	-0.017	0.597
Length of stay ↔ BE inclusivity	0.049	0.056
Age ↔ BE inclusivity	-0.001	0.966
Length of stay ↔ Age	0.301	< 0.001
Error in SC10: I intend to stay for long term in the area I live in ↔ Age	0.308	< 0.001
Error in SC9: I feel attached to the area I live in ↔ Error in SC10: I intend to stay for long term in the area I live in	0.095	< 0.001
Model 2		
BE inclusivity ↔ BE quality	0.199	< 0.001
Length of stay ↔ BE quality	0.046	0.101
Age ↔ BE quality	-0.017	0.594
Length of stay ↔ BE inclusivity	0.049	0.056
Age ↔ BE inclusivity	-0.002	0.957
Length of stay ↔ Age	0.300	< 0.001
Error in SC10: I intend to stay for long term in the area I live in. ↔ Age	0.309	< 0.001
Error in SC9: I feel attached to the area I live in ↔ Error in SC10: I intend to stay for long term in the area I live in	0.096	< 0.001