frontiers | Frontiers in Built Environment

TYPE Original Research
PUBLISHED 03 July 2024
DOI 10.3389/fbuil.2024.1420020

Check for updates

OPEN ACCESS

EDITED BY
Dan Li,
Shanghai Institute of Technology, China

REVIEWED BY
Yihsuan Lin,
University of Birmingham, United Kingdom
Lapyote Prasittisopin,
Chulalongkorn University, Thailand

*CORRESPONDENCE
Pawinee Iamtrakul,
pawinee@ap.tu.ac.th

RECEIVED 19 April 2024
ACCEPTED 07 June 2024
PUBLISHED 03 July 2024

CITATION
Iamtrakul P and Chayphong S (2024), Analyzing the link between built environment and physical activity: a spatial study in suburban area.
Front. Built Environ. 10:1420020.
doi: 10.3389/fbuil.2024.1420020

Analyzing the link between built environment and physical activity: a spatial study in suburban area

Pawinee Iamtrakul[1,2,3]* and Sararad Chayphong[1,2,3]

[1]Faculty of Architecture and Planning, Thammasat University, Pathum Tani, Thailand, [2]Department of Urban Environmental Planning and Development, Thammasat University, Bangkok, Thailand, [3]Center of Excellence in Urban Mobility Research and Innovation, Pathumthani, Thailand

Promoting physical activity is a significant concern that contributes to urban development, thereby fostering good health among city residents. This imperative highlights the interconnectedness between public health initiatives and the advancement of urban landscapes, reflecting the interdisciplinary nature of environmental science. Hence, this study aims to investigate the correlation between the built environment and access to physical activities within distinct local contexts. Utilizing the ordinary least squares estimation technique alongside spatial statistical analysis tools can facilitate the exploration of spatial disparities and interdependencies. Results pertaining to the built environment indicate significant differences within the built group context at a *p*-value level of 0.000. This suggests that within the local context, various activities, including those related to the transportation system, differ throughout the city. Findings regarding the link between the built environment and physical activity indicate that the relatively low R-squared values (0.10–0.20) may be attributed to the presence of grid areas with minimal walking distances. This finding underlines the key role of the built environment in promoting physical activity, highlighting the importance for urban planning and design to prioritize enhancements in active transportation infrastructure and increase access to urban activity nodes. This can be achieved by strategically distributing physical activity opportunities and ensuring accessibility via active transportation and public transit.

KEYWORDS

built environment, non-motorization, physical activity, quality of life, suburban, sustainable transportation

1 Introduction

The rapid urbanization witnessed over the past few decades has led to the expansion of cities both vertically and horizontally. Particularly noteworthy is the horizontal expansion, which often results in unguided urban development in cities lacking adequate planning. Consequently, the allocation of facilities and infrastructure encounters challenges in ensuring equitable and comprehensive service distribution. Physical activity is recognized as a fundamental factor in enhancing quality of life and overall wellbeing, especially in urban environments that prioritize both physical and mental health (Gill et al., 2013; Ho et al., 2019; Marquez et al., 2020). For instance, Puciato et al. (2023) examined the correlation between physical activity and quality of life among entrepreneurs, pinpointing a significant relationship between these factors. Similarly, Anokye et al. (2012) investigated the association between physical activity and quality of life, specifically in terms of health dimensions, with findings suggesting that higher levels of physical activity are linked to improved quality of life in this regard.

Limitations in access to physical activity are recognized as significant contributors to the rise in health issues (Puciato et al., 2023), serving as primary risk factors for Non-Communicable Diseases (NCDs), which are leading causes of global mortality (World Health Organization, 2010). Numerous studies corroborate the impact of urbanization on physical activity, particularly in expanding urban areas where the growth of cities is closely linked to human settlement patterns, construction of buildings, and infrastructure development. Collectively referred to as the built environment, these elements must support daily activities (Ewing et al., 2003; Frank et al., 2005; Ewing et al., 2014; Iamtrakul and Chayphong, 2023). The built environment encompasses the physical surroundings shaped by human activities, comprising various factors (e.g., land use mix, residential density, and accessibility to public transport). These factors are recognized as significant determinants influencing increased physical activity levels (Frank et al., 2005; Koohsari et al., 2017). The relationship between the built environment and physical activity offers opportunities for engaging in active and healthy behaviors through improved access to amenities and transportation options (Kärmeniemi et al., 2018).

One significant aspect of physical activity contributing to the sustainability of urban development is transportation-related physical activity. Research suggests that the allocation of infrastructure supporting walking, cycling, and public transportation has led to foster an engagement in transportation-related physical activity as modes of exercise (Handy et al., 2002; Kärmeniemi et al., 2018). It is evident that transportation-related physical activity not only serves as a form of exercise, but also facilitates access to various physical activities through a sustainable transportation system. Thus, promoting enhanced accessibility to physical activity via active and public transportation encourages heightened levels of physical activity or exercise engagement. However, despite the growing number of studies examining the correlation between the built environment and physical activity, it is noteworthy that a substantial proportion of these investigations have been carried out in regions outside of Asia, with Thailand notably underrepresented in this body of research. Consequently, findings from diverse contexts cannot be readily generalized to Thailand. Therefore, this study aims to investigate the correlation between the built environment and access to physical activities within specific local contexts, with a particular focus on the suburban areas of megacities, Pathum Thani. This focus is prompted by the current situation of unwalkable built environments prevalent in such areas of the vicinities of Bangkok. Recognizing that walking mode is crucial for building healthy cities and fostering a friendly environment, especially in low to medium-income societies where it represents the most economical mode of transportation, this research seeks to explore how the built environment can be optimized to encourage walking and enhance overall physical activity levels.

2 Literature review

2.1 Physical activity and its determinants

Allocating space, buildings, or activities that promote physical movement is peripherally linked to fostering physical, and mental wellbeing, as well as cultivating a favorable environment (Boone-Heinonen et al., 2010; Buck et al., 2019; Iamtrakul and Chayphong, 2023). Conversely, inadequate planning or a lack of emphasis on promoting physical activity can have detrimental effects on health, particularly contributing to the prevalence of non-communicable diseases such as obesity, hypertension, depression, or bipolar disorder (Sallis et al., 2012; Dun et al., 2021; Marquez et al., 2020). Physical activity encompasses spaces or structures designed to encourage physical movement, including activities associated with transportation systems such as walking, cycling, and the use of public transit (Kärmeniemi et al., 2018; Tcymbal et al., 2020). In many studies investigating physical activity, the objectives for analyzing various types of physical activity vary. For instance, in the study conducted by Sallis et al. (2012) and Pratt et al. (2004), the researchers examined the influence of the built environment on physical activity. It is uncovered that the physical activity factors considered were categorized into four main groups which includes recreation, occupational (school-related), transportation, and household activities. Salvo et al. (2011) investigated the characteristics of the built environment and their impact on physical activity, with a specific focus on activities in public parks. Similarly, Handy et al. (2002) explored the relationship between the built environment and physical activity, concentrating on active transportation modes such as walking and bicycling. In contrast, Zhang et al. (2022) examined public leisure facilities. In summary, physical activity encompasses areas, infrastructures, or transportation networks that facilitate various movements and activities involving physical exertion. It can be broadly categorized into two main components which are transportation-related physical activity and urban-related physical activity.

2.2 The association between the built environment and physical activity

The built environment encompasses built environment designed by humans to accommodate various daily activities (Transportation Research Board and Institute of Medicine, 2005). When examining physical activity from a behavioral standpoint, it involves participation in activities predominantly driven by physical exertion. From a physical standpoint, it involves areas, buildings, and transportation systems facilitating physically demanding activities. In this physical dimension, physical activities are presented as integral components of the built environment, encompassing areas, buildings, and transportation infrastructure constructed to support such activities. Physical activities associated with the built environment encompass various factors, including transportation systems and infrastructure (Handy et al., 2002; Smith et al., 2017), as well as activity-specific characteristics such as parks and sports facilities (Salvo et al., 2011; Zhang et al., 2022). Previous studies have highlighted the influence of the built environment on physical activity. For instance, Zhong et al. (2022) conducted a review and provided policy insights into the role of the built environment in promoting physical activity and health. Similarly, Tcymbal et al. (2020) conducted a systematic review shedding light on the relevance of the built environment to physical activity.

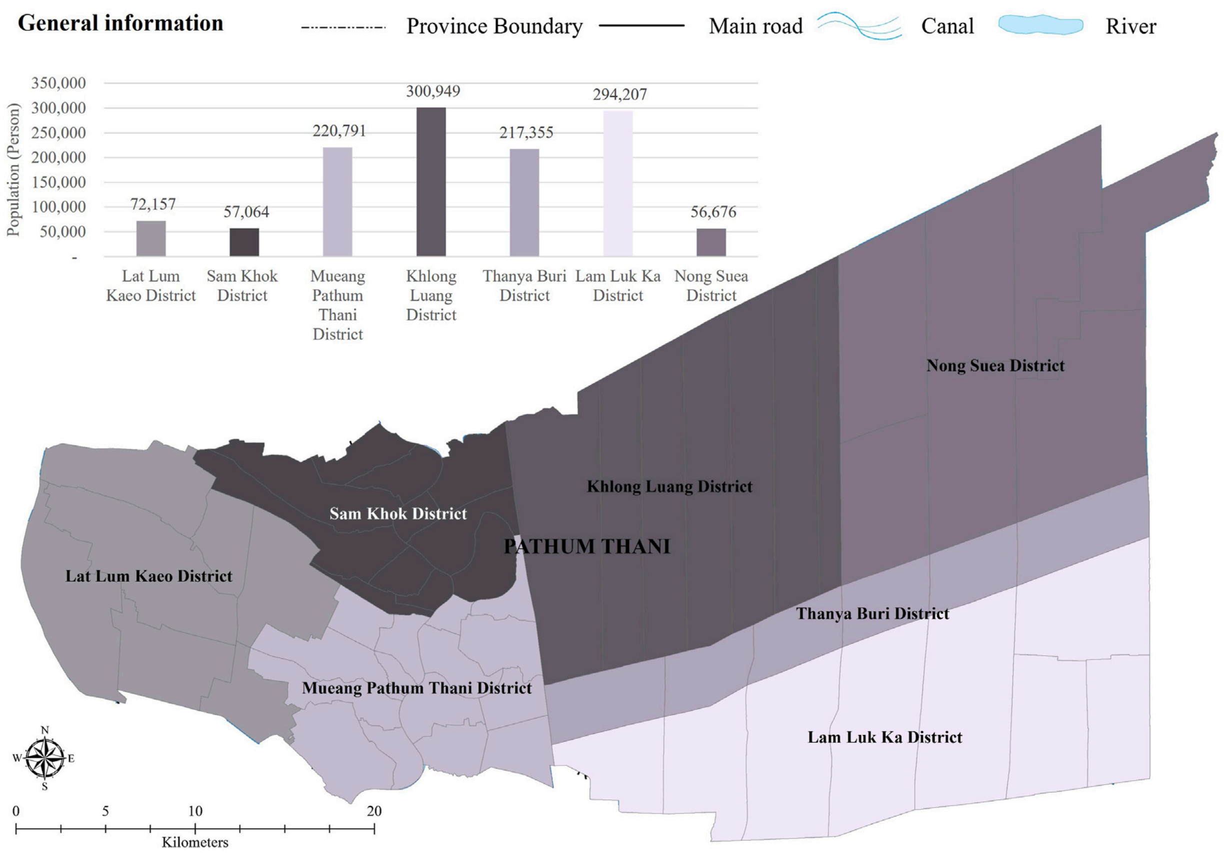


FIGURE 1
Study area: Pathum Thani province.

Koohsari et al. (2017) identified elements of the built environment related to physical activity, such as intersection density, street integration, and centrality. However, such studies have predominantly focused on subjective measurements of physical activity. Conversely, research on objectively measured relationships has been comparatively limited. Investigations within the physical context help illuminate variations in spatial characteristics and the distribution of physical activity, with implications for urban development inequality. For instance, Wei et al. (2016) examined walkability and physical activity within the built environment, considering land use characteristics. Their findings suggest that differences in local contexts contribute to variations in the relationships among factors, including trip characteristics. This consideration emphasizes that differences in local contexts contribute significantly to variations in the relationships among factors (Salvo et al., 2011; Wei et al., 2016). Variances in the built environment have enduring impacts on the activities of individuals residing within those environments. Changes in the built environment exert a notable influence on activities (Kärmeniemi et al., 2018). In essence, physical activity is believed to serve as a critical mechanism through which built environment settings and features impact individuals (Sallis et al., 2012). The evidence suggests both challenges and significant opportunities for enhancing urban wellbeing by exploring how the built environment can facilitate physical activity. Understanding the diverse nature of the built environment context is crucial, as it presents significant challenges and disparities in each context. This is particularly pertinent in developing countries undergoing rapid urbanization processes.

3 Methodology

3.1 Study area

The urbanization process is intently linked to varied development distributions across different areas. In Thailand, Bangkok stands out as a city experiencing intensive development compared to other provinces. However, due to the rapid expansion and growth of Bangkok, various activities and developments have extended into the surrounding metropolitan area. Pathum Thani province serves as a metropolitan area supporting Bangkok's expansion. The noteworthy aspect of Pathum Thani is that its suburban areas play a crucial role in supporting the development and expansion of the nation's capital. As a result, Pathum Thani province exhibits the unique characteristic of being both semi-urban and semi-rural. The province has developed a high density and variety of activities in areas close to the expanding capital, while remote areas still retain agricultural land, especially on the edges of the province (Iamtrakul and Chayphong, 2023). Functioning as a production base, export industry hub, and a key source of employment for the country (see Figure 1). It also serves as a

TABLE 1 Built environment and variables related to physical activity.

Aspects		Description	Measurement	References
Physical activity	Transportation-related physical activity	Public transportation	Network buffer zone in 500, 1,000 and 2,000 from location of bus stop or station (meters)	Kärmeniemi et al. (2018), Tcymbal et al. (2020)
	Urban-related physical activity	Sport facilities	Network buffer zone in 500 and 1,000 from location of sport facilities (meters)	Luo et al. (2022), Black et al. (2019), An et al. (2019)
		Playgrounds	Network buffer zone in 500, 1,000 and 2,000 from location of playground (meters)	
		Parks	Network buffer zone in 500, 1,000 and 2,000 from location of parks (meters)	
Built environment	Transportation	Intersection density	Intersection density as street connectivity was measured by density of intersection (more three intersections up) per grid, number per grids)	Frank et al. (2005), Rissel et al. (2015)
		Public transit availability	Availability of public transit per grid (number per grids)	Buck et al. (2019), Coogan et al. (2009)
	Land use	Land-use mix	Land-use mix was measured by the diversity of land use that more one type within grid (number per grids)	Frank et al. (2005), Wei et al. (2016), Kärmeniemi et al. (2018), Wei et al. (2016)
		Commercial density	Density of commercial use in grid (number per grids)	Wei et al. (2016)
		Residential density	Density of residential use in grid (number per grids)	Frank et al. (2005), Tcymbal et al. (2020)

transportation hub connecting the region with Bangkok. When examining the trend of urban expansion, it becomes evident that Pathum Thani province exhibits a tendency for continuous growth. However, in the past, the area of Pathum Thani province consisted of a mix of urban and agricultural zones. Presently, the surrounding areas of the province still comprise agricultural and residential zones, characterized by low density. This blend of urban and rural features poses challenges in the allocation of public facilities and infrastructures.

3.2 Data collection

The data analyzed in this study included the relationship between two primary factors (see Table 1) which are physical activity and built environment factors. The details of these factors are as follows: built environments encompass a variety of indicators, including intersection density, availability of public transit, land-use mix, commercial density, and residential density. Regarding physical activity, two main categories were considered which are transportation-related physical activity and urban-related physical activity. This includes factors such as access to public transportation, availability of sports facilities, playgrounds, and public parks. All data utilized in the study were objectively collected spatial data obtained from an online database.

3.3 Analysis

This study focuses on objectively and spatially measured variables at geographical scales to examine the association between the built environment and physical activity. The analysis process is illustrated as shown in Figure 2. Firstly, the contextual characteristics are examined using all five built environment factors (intersection density, public transit availability, land-use mix, commercial density, and residential density) through cluster analysis techniques, by employing Geographic Information Systems (GIS) and SPSS Version 28.0. Next, the characteristics within the clusters are examined to interpret their attributes. Secondly, the accessibility distances from walking conditions to four physical activity areas which are public transportation, sports facilities, playgrounds, and parks are evaluated within the network. This method is essential as it mirrors the city's effort in providing destinations that encourage walking, in line with urban facilities and amenities. The walking distances required to access these activities are categorized into four ranges: 500, 1,000, 2,000, and 3,000 m.

The distance within this network boundary is considered suitable for the study to effectively reflect the potential for walking to access relevant activities. For instance, Zhang and Huang, (2018) highlighted the use of a 1 km. Buffer size, which equates to an acceptable 15-min walking distance. The analysis was conducted on a grid area of 500 × 500 square meters, comprising a total of 1,620 grids. Computations were performed using spatial analysis to provide an overall perspective of the analysis. Finally, the association between the two factors was examined using the ordinary least squares estimation analysis technique, along with a spatial statistical analysis tool. This approach aids in understanding the relationship between factors in terms of spatial disparities.

4 Results

4.1 Built environment characteristic

This study concentrates on investigating the correlation and distribution of the built environment concerning physical activities. It does so by conducting research in Pathum Thani province, one of

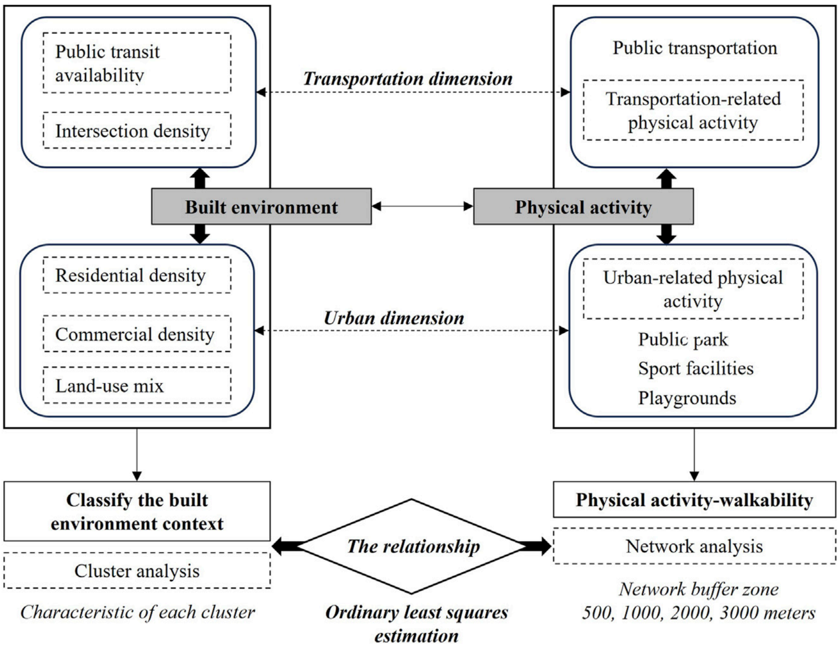


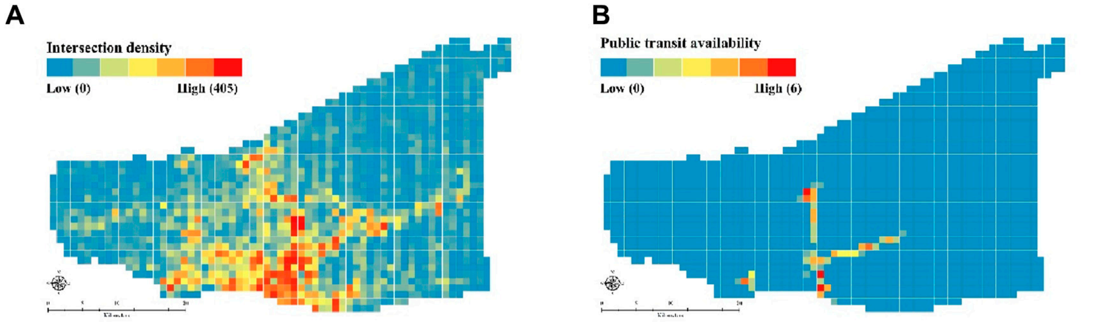
FIGURE 2
Framework.

the vicinity areas of Bangkok in supporting the expansion from the country's capital region. Consequently, Pathum Thani province exhibits a trend of continuous settlement expansion and indicate the important of this study area by reflecting upon the challenges associated with urban development in terms of promoting urban health. The literature review underlines the essential role played by these factors. Hence, it is imperative to comprehend the characteristics of the built environment within a given area as depicted in Figure 3. The figure illustrates those activities whether within the urban environment or the transportation system tend to concentrate in urban areas and extend to regions with lower residential densities. However, the depiction also highlights the developmental challenges in facilitating and promoting activities through public transport access.

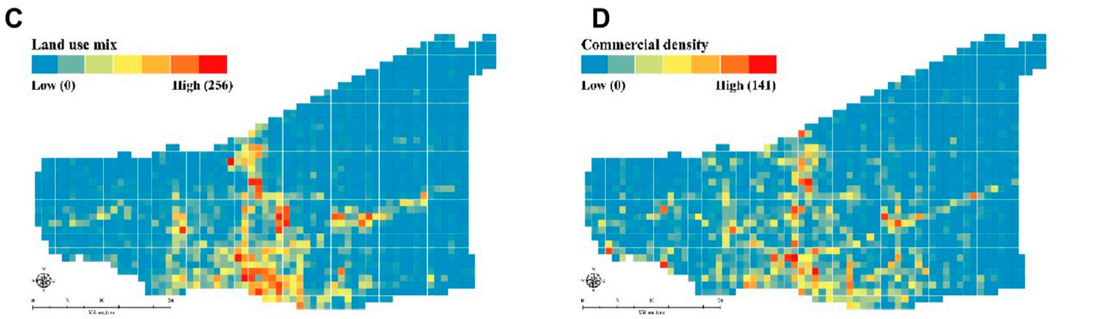
In reflection of this research, the examination of the complex relationships among built environment factors can be elaborated as depicted in Figure 4 which reveals compelling trends that delineate the directionality of these associations. Significantly, the correlation between the built environment component intertwined with the public transportation system and its usage demonstrates a noticeable range, typically ranging from 0.2 to 0.4.

This association is particularly noteworthy, with indicators such as land use mix exhibiting a robust association coefficient of 0.41, followed closely by commercial density at 0.35, and residential density at 0.18. These findings provide significant insights into the sophisticated interaction between public transit infrastructure and the adjoining built environment characteristics by emphasizing the multifaceted nature of urban mobility dynamics. Such reflections not only enrich our understanding of the factors shaping physical activity engagement but also provide actionable insights for policymakers and urban planners striving to craft environments that foster healthier with more active communities. In consideration to the associations observed between built environment factors linked to the public transport system, our analysis reveals an unambiguously contrasting relationship when examining the built environment aspect associated with road intersection density and its utilization. Remarkably, the correlation coefficients in this domain exceed the threshold of 0.6 or higher. It demonstrates a notably robust linkage between road infrastructure density and its usage patterns. Specifically, indicators such as land use mix demonstrate a convincing correlation coefficient of 0.67, followed by residential density at 0.73, and commercial density at 0.36, all of which are statistically significant at the 0.05 level.

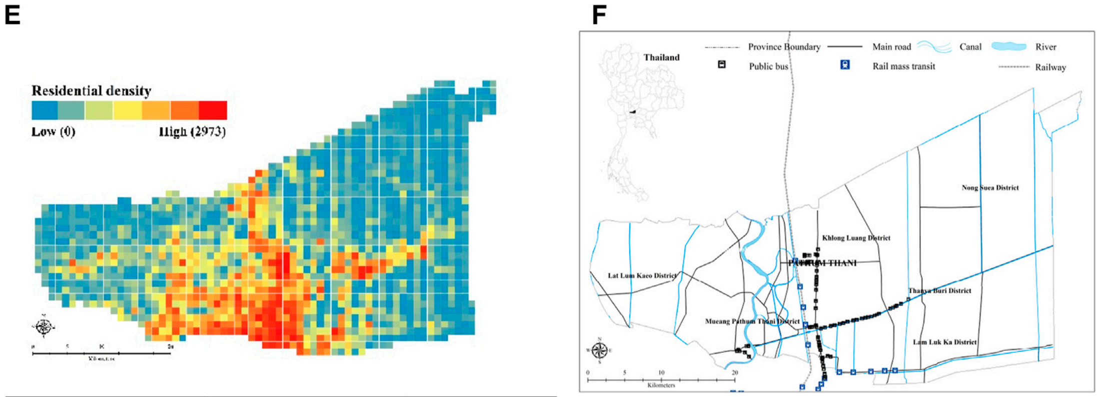
These findings demonstrate the correlation between the development of road networks and urban evolution which indicates a parallel trajectory between the expansion of road infrastructure and overarching urban developmental patterns. In contrast to the relationships identified within the domain of public transportation infrastructure, the robust correlations delineated within the framework of road intersection density illustrate an interdependent relationship wherein urban development and road network expansion progress simultaneously. Such insights could offer valuable perspectives for urban planners and policymakers, facilitating informed decision-making processes aimed at optimizing infrastructure development to align with broader urban development objectives and promote sustainable, efficient mobility solutions. After employing cluster analysis to clarify the character of the set of attributes of the local context derived from built environment factors, this research reveals compelling insights as depicted in Figure 5 and summarized in Table 2. These findings describe the characteristics of the area into three distinct clusters which each cluster offers unique profiles reflective of underlying urban dynamics. Cluster 1 stands out significantly, demonstrating the highest average availability of



Median	Mean	S.D.	Median	Mean	S.D.
0.047	0.096	0.131	0.000	0.013	0.87



Median	Mean	S.D.	Median	Mean	S.D.
0.016	0.059	0.120	0.014	0.057	0.101



Median	Mean	S.D.
0.024	0.069	0.113

FIGURE 3
Built environment characteristics of the study area.

public transit infrastructure with a notable value of 0.567. This is followed closely by indicators such as land-use mix, intersection density, commercial density, and residential density, each contributing to the multifaceted fabric of the urban landscape. Notably, the pronounced prominence of public transit availability within Cluster 1 illustrates the key role of transit accessibility in shaping the local context which indicates a robust infrastructure framework encouraging to facilitating efficient mobility options for a variety group of commuters.

These insights help in recommending valuable perspectives for understanding the association between built environment characteristics and local context dynamics. By delineating distinct clusters based on key factors, this research provides a foundation for informed decision-making processes aimed at tailoring urban planning strategies to align with the unique needs and priorities of diverse mobility contexts. Such reflections pave the way for the formulation of targeted interventions aimed at optimizing infrastructure development, enhancing mobility options, and fostering vibrant, resilient transportation plans for sustainable growth and development.

The findings from the analysis of Cluster 2 present intriguing revelations regarding a geographical region distinguished by unique urban attributes, fundamentally shaped by the prevalence of intersection density as the predominant factor. The intersection

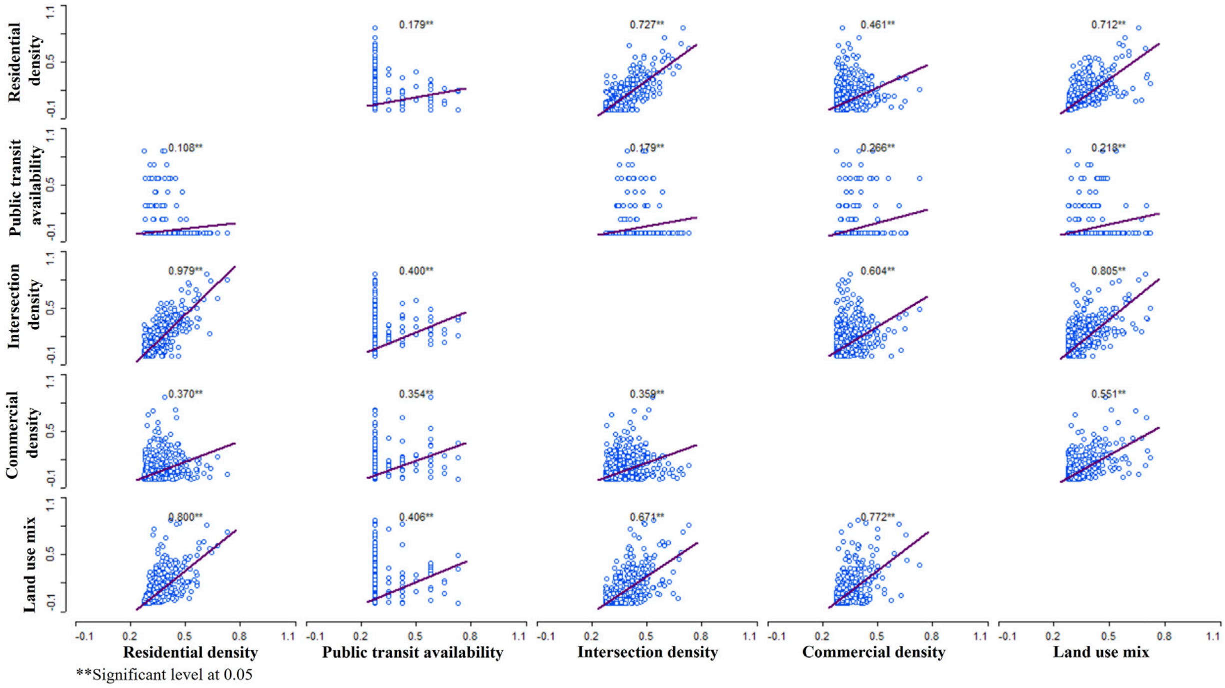


FIGURE 4
Scatter plot matrix of various built environments.

density of 0.350 within this cluster indicates a landscape typified by a complex arrangement of roadways and junctions, implying heightened vehicular interconnectivity and accessibility. Furthermore, the notable prominence of residential density at 0.298 highlights the residential-centric nature of this locale which is presented as an indicative of a community fabric primarily oriented towards housing and residential amenities. In contrast to Cluster 1, which emphasizes the substantial presence of public transportation infrastructure and commercial enterprises, Cluster 2 reveals a landscape primarily characterized by residential amenities and vehicular connectivity. This result highlights the diversity of urban contexts and the relationship between built environment factors which demonstrates the multifaceted nature of urban landscapes. By highlighting the distinct characteristics of Cluster 2, this result of analysis provides valuable insights for urban planners and policymakers dealing with the complexities of urban development by emphasizing on the importance of tailoring interventions and strategies to align with the unique needs and priorities of diverse contexts of different areas, ultimately fostering sustainable, inclusive urban environments characterized by resilience and vibrancy.

The identification of Cluster 3 shows a distinctive urban landscape marked by complicated socio-spatial dynamics, emblematic of a locality where personal vehicle travel predominates. With intersection density emerging as the leading factor, although at a relatively lower average of 0.054 compared to other clusters, this cluster embodies a landscape characterized by a network of roadways facilitating vehicular mobility. The concurrent presence of residential and commercial densities further underlines the mixed-use nature of this area which is indicative of a vibrant urban fabric marked by a diverse array of activities. However, unlike Cluster 1 and Cluster 2, where public transit availability played a more definite role, Cluster 3 presents a contrast with its relatively minimal public transit accessibility which is indicated by an average score of 0.001. This signifies a reliance on personal vehicles for travel which is an indicative of a landscape where public transit options may be limited or less accessible. Furthermore, the spatial distribution of activity types within Cluster 3, predominantly along the periphery of the urban area and distant from the city center illustrates decentralized development patterns. This spatial configuration may have implications for travel behavior and accessibility by highlighting the importance of considering spatial context in urban planning and transportation infrastructure development. Summary, the characterization of Cluster 3 offers valuable insights into the diverse array of urban landscapes and travel patterns observed within the study area. By revealing the distinct socio-spatial dynamics, this research could provide a tool on an establishment of a foundation for targeted interventions aimed at optimizing mobility options, enhancing accessibility, and fostering sustainable urban development tailored to the unique needs and characteristics of diverse community contexts.

4.2 Objectively and spatially varying measurements at geographical scales: linking the built environment to physical activity

This section examines the walking distances to all four physical activities which are divided into four distance ranges of 500, 1,000, 2,000, and 3,000 m. These distance intervals within the network boundary are deemed suitable for the study, as they reflect the

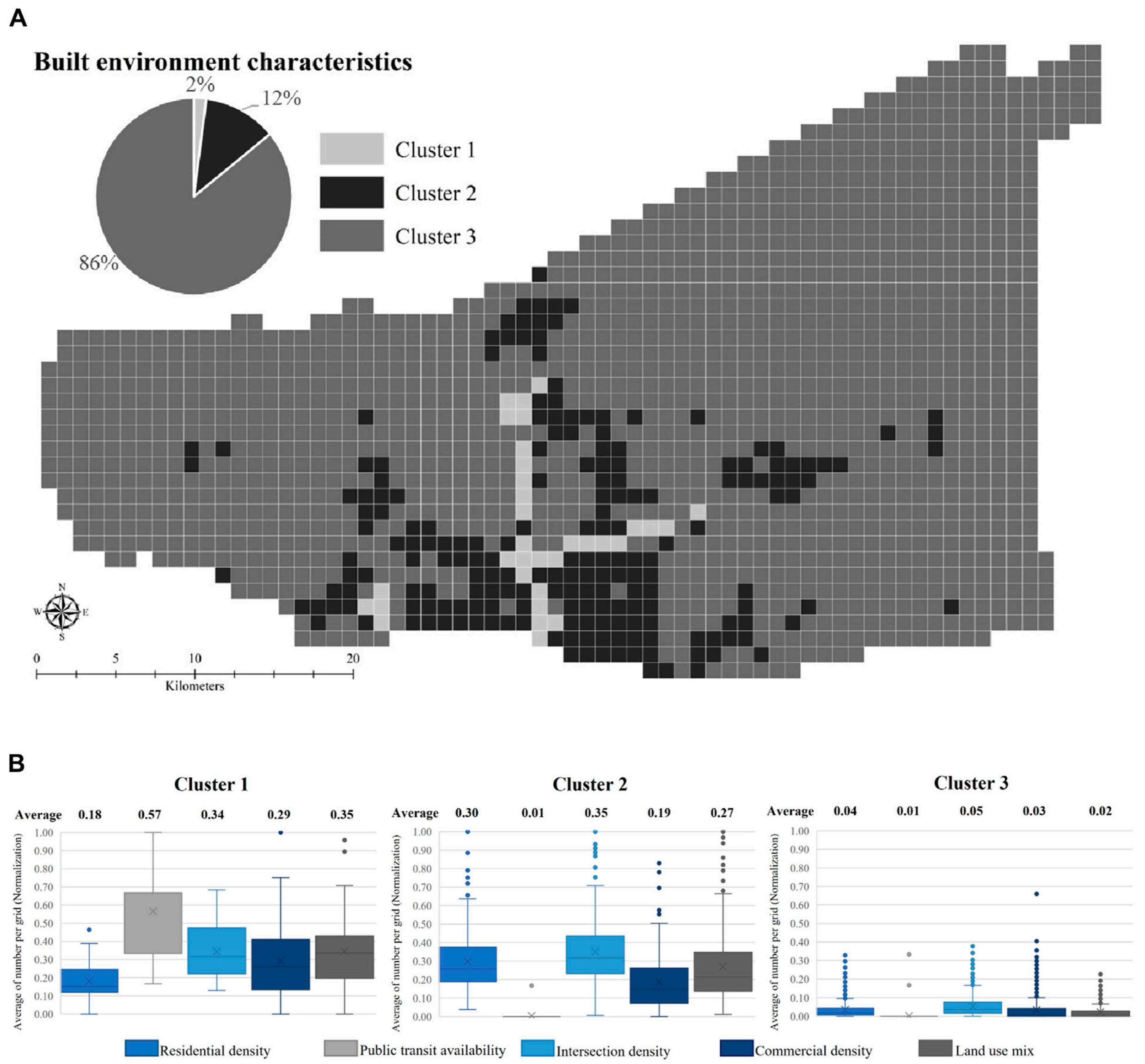


FIGURE 5
Cluster analysis of the built environment.

TABLE 2 Distinguishing features of the built environment.

Aspect	Cluster 1			Cluster 2			Cluster 3			Mean square	Sig
	Min	Max	Average	Min	Max	Average	Min	Max	Average		
Intersection density	0.130	0.683	0.343	0.006	1.000	0.350	0.000	0.378	0.054	8.515	0.000
Public transit availability	0.167	1.000	0.567	0.000	0.167	0.004	0.000	0.333	0.001	5.144	0.000
Land-use mix	0.000	0.957	0.345	0.012	1.000	0.270	0.000	0.242	0.022	6.621	0.000
Commercial density	0.000	1.000	0.293	0.000	0.844	0.187	0.000	0.659	0.034	2.953	0.000
Residential density	0.000	0.464	0.182	0.038	1.000	0.298	0.000	0.329	0.035	6.129	0.000

potential for walking to access these activities effectively. Figure 6 illustrates that most physical activities are concentrated within the urban area and along the main roads which serve as conduits connecting travel from Bangkok to other regions.

The defined characteristics within the three urban area groups provide significant insights into the varying potentials for pedestrian access to physical activity areas across clusters. Clusters 1 and 2 notably emerge as environments particularly supportive of

FIGURE 6
Physical activity and walkability. **(A)**. Sport facilities, **(B)**. Public parks, **(C)**. Playgrounds, **(D)**. Public transports.

promoting active living and engagement in physical activities, attributed to their distinctive urban characteristics and built environment attributes. Cluster 1 is characterized by a robust public transportation system and a high density of commercial activities, creating an environment favorable for pedestrian access to physical activity areas. The presence of robust public transit infrastructure, combined with a mix of commercial and residential densities, fosters a vibrant urban fabric contributing to walking and engagement in physical activities. Similarly, Cluster 2 highlights its characteristics in terms of intersection density and residential density, indicating a landscape well-suited for pedestrian accessibility and engagement in physical activities. The prevalence of residential infrastructure along with a dense network of roadways and intersections, fosters a pedestrian-friendly environment conducive to walking and active mobility.

In contrast, Cluster 3 with its reliance on personal vehicle travel and decentralized development patterns which presents a comparatively lower potential for pedestrian access to physical activity areas. The spatial distribution of activity types along the periphery of the urban area and the limited accessibility to public transit may pose challenges for pedestrians seeking to engage in physical activities. Taken together, these findings highlight the importance of considering the built environment and urban context in promoting active living and facilitating pedestrian access to physical activity areas. By leveraging insights gathered from cluster analysis, policymakers and urban planners can tailor interventions and strategies to enhance pedestrian infrastructure, improve accessibility, and foster healthier, more vibrant communities across diverse urban landscapes. Based on the exploration of the correlation between built environment factors and access to physical activities, Table 3 reveals a compelling association between built environment attributes and access to physical activity opportunities. Notably, four variables emerge as significant predictors of access to physical activities (public park, playground, public transit, and sport facility) by highlighting the multifaceted interplay between urban design and active living.

Firstly, the availability of public transit infrastructures as a noteworthy predictor, with a coefficient of 513.21. This suggests that areas with greater accessibility to public transit are more likely to facilitate access to physical activities within public parks,

TABLE 3 Objectively and spatially varying measurements at geographic scales of the relationship between the built environment and physical activity.

Aspects	Public park		Playground		Public transit		Sport facility	
	Coef.	Probability	Coef.	Probability	Coef.	Probability	Coef.	Probability
Intersection density	41.60	0.824	536.99	0.010	983.69	0.001	−645.94	0.024
Public transit availability	513.21	0.001	334.14	0.052	−223.94	0.259	279.12	0.232
Land-use mix	670.64	0.001	322.43	0.143	−863.66	0.001	261.11	0.381
Commercial density	606.677	0.001	52.73	0.775	878.27	0.001	−242.25	0.334
Residential density	776.58	0.001	848.56	0.001	1,585.59	0.027	300.59	0.387
R-squared	0.162		0.115		0.141		0.011	

indicative of the pivotal role of transportation infrastructure in shaping mobility patterns and promoting active lifestyles. Similarly, the presence of a diverse land-use mix emerges as a significant determinant with a coefficient of 670.64. The results demonstrate the importance of mixed-use environments in fostering accessibility to physical activity facilities within public parks, emphasizing the synergistic relationship between land use patterns and active living opportunities. Moreover, commercial density demonstrates a strong association with access to physical activities, as evidenced by its coefficient of 606.68. This implies that areas with a higher density of commercial establishments are more likely to provide a diverse range of recreational opportunities within public parks, thereby enhancing accessibility and encouraging engagement in physical activities. Lastly, residential density emerges as a strong predictor with a coefficient of 776.58. The results emphasize the role of residential neighborhoods in fostering access to physical activity attractiveness within public parks by highlighting the importance of population density in shaping urban landscapes and promoting active living.

Overall, these findings underline the significance of built environment factors in shaping access to physical activities within public parks by offering valuable insights for urban planners and policymakers seeking to promote healthier, more inclusive communities. Utilizing these insights, stakeholders can develop interventions and strategies aimed at enhancing urban environments to optimize access to physical activity opportunities, thus promoting healthier and more dynamic urban landscapes. The examination of built environment factors in relation to access to physical activities reveals interesting patterns, particularly with respect to specific activity areas such as playgrounds and public transit areas. Within playgrounds, two variables emerge as noteworthy predictors which include intersection density and residential density. The coefficient values of 536.99, and 848.56, respectively underline the importance of urban design features and residential density in shaping accessibility to recreational opportunities for children and families within playground settings.

In contrast, access to physical activities within public transit areas is influenced by a more diverse array of built environment factors. Notably, four variables demonstrate significant associations which comprise intersection density, land-use mix, commercial density, and residential density. The significant coefficient values ranging from 983.69 to 1,585.59 highlight the multifaceted nature of accessibility within transit areas and the interaction between various urban design elements. The distinction of intersection density as a predictor in both playgrounds and public transit areas highlights its role as a key determinant of accessibility and mobility patterns within urban environments. Residential density emerges as another consistent predictor reflecting the importance of population density in shaping access to physical activity amenities across different contexts. Moreover, the significance of land-use mix and commercial density in predicting access to physical activities within public transit areas emphasizes the importance of diverse urban environments in fostering active living opportunities. These findings demonstrate the complex relationship between built environment factors and access to physical activities which could offer valuable insights for urban planners and policymakers striving to create healthier, more inclusive communities.

Furthermore, stakeholders can develop targeted interventions and strategies aimed at optimizing urban environments to promote active living and enhance accessibility to physical activity amenities for residents of all ages and backgrounds. The examination of built environment factors concerning physical activities in sport facilities reveals a notable association with intersection density, as evidenced by its coefficient of −645.94. This suggests that areas characterized by a higher density of intersections may offer increased accessibility to sport facilities, potentially facilitating engagement in physical activities such as organized sports and recreational pursuits. However, it is important to note the relatively low R-squared values observed in the analysis result. This could be attributed to the presence of grid areas with minimal walking distance to physical activities, constituting less than one percent of the total number of grids. This limited representation of certain areas within the dataset may influence the resulting relationship trends, potentially contributing to the lower explanatory power of the model.

Despite these limitations, the identification of intersection density as a significant predictor highlights the importance of transportation infrastructure in shaping accessibility to sport facilities and promoting active lifestyles. By recognizing the role of built environment factors in facilitating physical activity engagement, urban planners and policymakers can design interventions aimed at optimizing urban landscapes to support healthier and more active communities. Moving forward, further research efforts could focus on refining the methodology and expanding the scope of analysis to capture a more comprehensive understanding of the complex interactions between built environment factors and access to physical activities. By addressing these methodological considerations and employing advanced analytical techniques, future studies can contribute to the development of evidence-based strategies for promoting active living and enhancing quality of life in urban environments.

The examination of statistical significance values points out the vital role of intersection density and residential density in shaping physical activity patterns within urban environments. These findings highlight the significant impact of built environment factors on physical activity engagement, with notable implications for various activity settings. Of particular interest are physical activities related to public parks and public transit where environmental factors exhibit considerable significance. In these contexts, intersection density and residential density emerge as key predictors which reflect the influence of transportation infrastructure and population density on accessibility and mobility patterns. The observation that environmental factors account for 4 out of 5 significant factors underlines the importance of considering the built environment in promoting active living and enhancing quality of life. By recognizing the role of intersection density, residential density, and other built environment factors, policymakers and urban planners can design interventions aimed at optimizing urban landscapes to support healthier, more active communities. Furthermore, these findings emphasize the interconnected nature of urban design and public health outcomes, highlighting the need for interdisciplinary approaches to address complex challenges related to physical inactivity and sedentary lifestyles. By integrating insights from urban planning, public health, and other relevant disciplines, finally key stakeholders can develop comprehensive strategies for creating built environments that foster active living and promote overall wellbeing.

5 Discussion

The study results suggest a very low correlation between the built environment and physical activity, potentially attributable to limitations in the physical activity data. Comparing these findings with similar studies, Wei et al. (2016) investigated walkability, physical activity, and the built environment by examining land use characteristics. Their study revealed that land use mix lacked significance for physical activities at geographic scales due to variations in activity trip types and the low level of land use mix within the study area context. While Kärmeniemi et al. (2018) study highlights that land use mix is associated with increased physical activity, including the use of public transportation, this consideration underlines that differences in local context contribute to variations in the relationship among factors. This finding aligns with Salvo et al. (2011) which emphasizes important recommendations concludes the research results may differ from those in high-income countries, and policies or findings from studies in other contexts should not disregard the local context. The results of this study indicate that residential density is more closely associated with physical activity across various types than other factors, such as land use mix, public transit, and intersection density. When considering walkability for accessing visual activities, the positive relationship between residential density and visual activities reflects the perspective of urban planning, particularly at the neighborhood scale, which promotes wellbeing and health. Focusing on the ability to walk within a reasonable distance from one's residence to access activities and amenities presents a challenging issue in urban planning and design. The built environment factors associated with land use are considered significant as they reflect the type, diversity, and density of activities. Many studies indicate that activity diversity is more likely to facilitate walking (Habibian and Hosseinzadeh, 2018; Fonseca et al., 2022). This relationship can be attributed to the planning of infrastructure and various facilities within residential areas, which prioritize the distribution of activities. Consequently, individuals can access and engage in activities during their free time or leisure hours. Moreover, this proximity enables individuals to walk to activities within the residential area itself. However, the density of commercial activities and the mix of land uses emerge as secondary factors, following residential density. Supporting these factors are physical activities facilitated by public parks and public transit. These activities serve as public amenities designed to accommodate large groups or the entire population of the city. Particularly, the public transportation system plays a significant role in dispersing such activities across mixed-use and commercial areas.

The findings demonstrate the sophisticated relationship between built environmental factors, travel behavior, and physical activity, highlighting them as key components in urban mobility and public health considerations. It sheds light on how environmental features not only act as attractions, drawing individuals towards specific destinations within an area, but also notably influence the direction and extent of travel movements, thus molding patterns of engagement in physical activity (Joh et al., 2015). Particularly noteworthy is the exploration of transportation-related physical activity which highlights the dynamic interaction between the distribution of public transportation and individuals' accessibility to physical activity opportunities. This discussion emphasizes the diverse urban environments where the availability and proximity of bus stops become fundamental factors influencing the active lifestyle choices of inhabitants. Furthermore, the discourse brings attention to the significant distances individuals often need to traverse to access physical activity amenities which demonstrates a critical challenge in promoting healthy behaviors within urban landscapes (Handy et al., 2002; Salvo et al., 2011; Smith et al., 2017; Zhang et al., 2022). However, the promotion of public transport development in the suburban areas of the capital is still in progress. Analysis of the density of public bus stops reveals a concentration of public transport systems limited to the central city area, leaving main roads, particularly in remote areas, underserved. These issues are considered significant challenges in urban development planning. Promoting the development of public transport systems in terms of distance and bus stop density benefits the establishment of a sustainable transportation system. Such initiatives not only positively correlate with walking but also with active lifestyles, leading to improved health outcomes (Buck et al., 2015). This analysis not only enriches our understanding of the complex dynamics at play but also emphasizes the need for innovative urban planning strategies that prioritize equitable access to physical activity resources. Such approaches are crucial for fostering healthier and more vibrant communities.

The imperative for cities to enhance access to both active and public transport systems is emphasized by a burgeoning body of research. Notably, multiple studies have clarified the positive correlation between the availability of transit options, gauged by metrics such as the abundance and proximity of transit stops, and heightened levels of transportation-related walking. For instance, Joh et al. (2015) reveals this association as do the findings of Pikora et al. (2005) which emphasizes a robust consistency across diverse urban contexts. This empirical evidence accentuates the crucial role of the built environment in incentivizing physical activity, thereby amplifying the imperative for urban planning and design paradigms to prioritize the augmentation of active transportation infrastructure and the amplification of access to physical activity amenities. This scholarly discourse not only underlines the symbiotic relationship between urban form and public health outcomes, but also underlines the exigency for interdisciplinary approaches that integrate urban planning, transportation engineering, and public health perspectives to cultivate healthier and more sustainable urban environments.

The endeavor to promote healthier and more sustainable urban landscapes through the promotion of physical activity and the facilitation of access via active transportation and public transit holds profound implications for mitigating overreliance on automobiles. While acknowledging the influences of individual and social factors on physical activity engagement, present research consistently highlights the paramount significance of a thoughtfully built environment. Studies such as those conducted by Ding et al. (2011) and Brownson et al. (2009) rationally describes the key role in environmental design by shaping patterns of physical activity. This research also emphasizes the imperative for urban planners, policymakers, and designers to utilize evidence-based strategies that prioritize the creation of environments supportive of active living. By fostering walkable neighborhoods, enhancing bike infrastructure, and strengthening public transit networks, cities can not only improve public health outcomes, but also promote vibrant, interconnected communities characterized by reduced car dependency and enhanced quality of life. However, the results of this study indicate that the association of built environmental factors with walkability to access physical activities is relatively weak, possibly due to the low level of walkability for accessing physical activities and its lack of spatial distribution. Therefore, future studies should incorporate a perspective on people's subjective considerations of physical activity access. This approach would help emphasize the importance of allocating physical activity within an area, as the mere presence of activities does not ensure access or participation. Enabling future studies to provide comprehensive results and incorporate a variety of subjective and objective perspectives will contribute to a deeper understanding of the complex relationship between built environments and physical activity.

6 Conclusion

In conclusion, this research explores the complex interaction between the built environment and physical activity by employing an innovative approach that integrates objectively measured spatial data across varying geographical scales. By employing the ordinary least squares estimation analysis technique, this research reveals the complex relationship between these critical factors and shed light on spatial differences that underpin their association. Our findings emphasize the importance of intersection density and residential density as influential determinants of physical activity levels and reveal their statistically significant impact. This comprehensive understanding contributes to the promising evidence on urban health by emphasizing the imperative for evidence-based urban planning interventions aimed at fostering environments in promoting an active living. By embracing interdisciplinary methodologies and utilizing spatial analytics, the results of this research can pave the way for the creation of healthier and more vibrant communities characterized by enhanced physical activity engagement and improved public health outcomes.

According to the results of the analysis, while the association of the built environment with access to physical activities is relatively weak, this may be attributed to the relatively low level of physical activity accessibility through walking. However, the results highlight the significant disparities in urban contexts attributed to built environmental factors. Findings concerning the built context environment reveal substantial variations within the built group environment, with significance levels reaching 0.000. This indicates a diversity of activities within the local context, including those related to the transportation system. These contextual differences help guide the direction of design and planning in the built environment. The findings revealed in this study emerge as powerful catalysts for transformative urban planning and development efforts aimed at cultivating vibrant, health-conscious cities. They illustrate the sophisticated association between physical activity engagement and the built environment, elaborating a pathway towards prioritizing and promoting active living within urban landscapes. Importantly, our findings advocate for a paradigm shift in urban policy discourse, emphasizing interventions that embrace a holistic approach to public health. At the core of these interventions are strategies for improving the built environment, such as enhancing levels of land-use mix, increasing accessibility to public transit networks, and promoting higher residential densities. These proactive measures promise tangible, long-term public health dividends while laying the groundwork for promoting an all-encompassing built environment that enhances overall quality of life. By considering these insights and adopting a multifaceted approach to urban planning, policymakers and stakeholders can collaborate toward establishing healthier, more resilient cities. These cities can serve as beacons of wellbeing and vitality for generations to come.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

PI: Conceptualization, Formal Analysis, Funding acquisition, Methodology, Supervision, Validation, Writing–original draft, Writing–review and editing. SC: Data curation, Formal Analysis, Investigation, Project administration, Validation, Visualization, Writing–original draft, Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. The authors gratefully acknowledge the supported by the Thailand Science Research and Innovation Fundamental Fund fiscal year 2023, Contract No. TUFF05/2566, under project "The Quality of Life in Sustainable Urban Mobility, Suburban Areas, Thailand". This research was also conducted by the Center of Excellence in Urban Mobility Research and Innovation (UMRI), Thammasat University, Pathum Thani, Thailand.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Anokye, N. K., Trueman, P., Green, C., Pavey, P. G., Taylor, T. S., et al. (2012). Physical activity and health related quality of life. *BMC Pub. Health.* 12, 624. doi:10.1186/1471-2458-12-624

An, R., Shen, J., Yang, Q., and Yang, Y. (2019). Impact of built environment on physical activity and obesity among children and adolescents in China: A narrative systematic review. *J. Sport. Health. Sci.* 8 (2), 153–169. doi:10.1016/j.jshs.2018.11.003

Black, N., Johnston, D. W., Propper, C., and Shields, M. A. (2019). The effect of school sports facilities on physical activity, health and socioeconomic status in adulthood. *Soc. Sci. Med.* 220, 120–128. doi:10.1016/j.socscimed.2018.10.025

Boone-Heinonen, J., Guilkey, D. K., Evenson, K. R., and Gordon-Larsen, P. (2010). Residential self-selection bias in the estimation of built environment effects on physical activity between adolescence and young adulthood. *Int. J. Behav. Nutr. Phys. Act.* 7, 70. doi:10.1186/1479-5868-7-70

Brownson, R. C., Hoehner, C. M., Day, K., Forsyth, A., and Sallis, J. F. (2009). Measuring the built environment for physical activity: state of Science. *Am. J. Prev. Med.* 36 (4), S99–S123.e12. doi:10.1016/j.amepre.2009.01.005

Buck, C., Eiben, G., Lauria, F., Konstabel, K., Page, A., Ahrens, W., et al. (2019). Urban Moveability and physical activity in children: longitudinal results from the IDEFICS and I.Family cohort. *Int. J. Behav. Nutr. Phys. Act.* 16 (1), 128. doi:10.1186/s12966-019-0886-2

Buck, C., Tkaczick, T., Pitsiladis, Y., De Bourdehaudhuij, I., Reisch, L., Ahrens, W., et al. (2015). Objective measures of the built environment and physical activity in children: from walkability to moveability. *J. Urban Health* 92 (1), 24–38. doi:10.1007/s11524-014-9915-2

Coogan, P. F., White, L. F., Adler, T. J., Hathaway, K. M., Palmer, J. R., and Rosenberg, L. (2009). Prospective study of urban form and physical activity in the Black Women's Health Study. *Am. J. Epidemiol.* 170 (9), 1105–1117. doi:10.1093/aje/kwp264

Ding, D., Sallis, J. F., Kerr, J., Lee, S., and Rosenburg, D. E. (2011). Neighborhood environment and physical activity among youth: a Review. *Am. J. Prev. Med.* 41 (4), 442–455. doi:10.1016/j.amepre.2011.06.036

Dun, Q., Duan, Y., Fu, M., Meng, H., Xu, W., Yu, T., et al. (2021). Built environment, physical activity, and obesity of adults in pingshan district, shenzhen city in southern China. *Ann. Hum. Biol.* 48 (1), 15–22. doi:10.1080/03014460.2021.1886324

Ewing, R., Meakins, G., Hamidi, S., and Nelson, A. C. (2014). Relationship between urban sprawl and physical activity, obesity, and morbidity – update and refinement. *Health and Place* 26, 118–126. doi:10.1016/j.healthplace.2013.12.008

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., and Raudenbush, S. (2003). Relationship between urban sprawl and physical activity, obesity, and morbidity. *Am. J. Health Promot* 18, 47–57. doi:10.4278/0890-1171-18.1.47

Fonseca, F., Ribeiro, P. J. G., Conticelli, E., Jabbari, M., Papageorgiou, G., Tondelli, S., et al. (2022). Built environment attributes and their influence on walkability. *Int. J. Sustain. Transp.* 16 (7), 660–679. doi:10.1080/15568318.2021.1914793

Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., and Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *Am. J. Prev. Med.* 28 (2), 117–125. doi:10.1016/j.amepre.2004.11.001

Gill, D. L., Hammond, C. C., Reifsteck, E. J., Jehu, C. M., Williams, R. A., Adams, M. M., et al. (2013). Physical activity and quality of life. *J. Prev. Med. Public Health* 46 (1), S28–S34. doi:10.3961/jpmph.2013.46.S.S28

Habibian, M., and Hosseinzadeh, A. (2018). Walkability index across trip purposes. *Sustain. Cities Soc.* 42, 216–225. doi:10.1016/j.scs.2018.07.005

Handy, S. L., Boarnet, M. G., Ewing, R., and Killingsworth, R. E. (2002). How the built environment affects physical activity: views from urban planning. *Am. J. Prev. Med.* 23 (2), 64–73. doi:10.1016/S0749-3797(02)00475-0

Ho, K. Y., Li, W. H. C., Lam, K. W. K., Wei, X., Chiu, S. Y., Chan, C. G., et al. (2019). Relationships among fatigue, physical activity, depressive symptoms, and quality of life in Chinese children and adolescents surviving cancer. *Eur. J. Oncol. Nurs.* 38, 21–27. doi:10.1016/j.ejon.2018.11.007

Iamtrakul, P., and Chayphong, S. (2023). Factors affecting the development of a healthy city in Suburban areas, Thailand. *J. Urban Manag.* 12, 208–220. doi:10.1016/j.jum.2023.04.002

Joh, K., Chakrabarti, S., Boarnet, M. G., and Woo, A. (2015). The walking renaissance: a longitudinal analysis of walking travel in the Greater Los Angeles Area, USA. *Sustainability* 7 (1), 8985–9011. doi:10.3390/su7078985

Kärmeniemi, M., Lankila, T., Ikäheimo, T., Koivumaa-Honkanen, H., and Korpelainen, R. (2018). The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. *Ann. Behav. Med.* 52 (3), 239–251. doi:10.1093/abm/kax043

Koohsari, M. J., Owen, N., Cole, R., Mavoa, S., Oka, K., Hanibuchi, T., et al. (2017). Built environmental factors and adults' travel behaviors: role of street layout and local destinations. *Prev. Med.* 96, 124–128. doi:10.1016/j.ypmed.2016.12.021

Luo, P., Yu, B., Li, P., and Liang, P. (2022). Spatially varying impacts of the built environment on physical activity from a human-scale view: Using street view data. *Front. Environ. Sci.* 10, 1021081. doi:10.3389/fenvs.2022.1021081

Marquez, D. X., Aguiñaga, S., Vásquez, P. M., Conroy, D. E., Erickson, K. I., Hillman, C., et al. (2020). A systematic review of physical activity and quality of life and well-being. *Transl. Behav. Med.* 10 (5), 1098–1109. doi:10.1093/tbm/ibz198

Pikora, T. J., Giles-Corti, B., Knuiman, M. W., Bull, F. C., Jamrozik, K., and Donovan, R. J. (2005). Neighbourhood environmental factors correlated with walking near home: using SPACES. *Med. Sci. Sports Exerc* 38 (4), 708–714. doi:10.1249/01.mss.0000210189.64458.f3

Pratt, M., Macera, C. A., Sallis, J. F., O'Donnell, M., and Frank, L. D. (2004). Economic interventions to promote physical activity: application of the SLOTH model. *Am. J. Prev. Med.* 27 (3), 136–145. doi:10.1016/j.amepre.2004.06.015

Puciato, D., Bączkowicz, D., and Rozpara, M. (2023). Correlations between physical activity and quality of life in entrepreneurs from Wrocław, Poland. *BMC Sports Sci. Med. Rehabil.* 15, 13. doi:10.1186/s13102-023-00624-4

Rissel, C., Greaves, S., Li Ming, W., Crane, M., and Standen, C. (2015). Use of and short-term impacts of new cycling infrastructure in inner-Sydney, Australia: a quasi-experimental design. *Int. J. Behav. Nutr. Phys. Act.* 12, 1–8. doi:10.1186/s12966-015-0294-1

Salvo, D., Reis, R. S., Stein, A. D., Rivera, J., Martorell, R., and Pratt, M. (2011). Characteristics of the built environment in relation to objectively measured physical activity among Mexican adults. *Prev. Chronic Dis.* 11, 140047. doi:10.5888/pcd11.140047

Sallis, J. F., Floyd, M. F., Rodríguez, D. A., and Saelens, B. E. (2011). Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation* 125 (5), 729–737.

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A., et al. (2017). Systematic literature review of built environment effects on physical activity and active transport—an update and new findings on health equity. *Int. J. Behav. Nutr. Phys. Act.* 14 (1), 158. doi:10.1186/s12966-017-0613-9

Tcymbal, A., Demetriou, Y., Kelso, A., Wolbring, L., Wunsch, K., Wäsche, H., et al. (2020). Effects of the built environment on physical activity: a systematic review of longitudinal studies taking sex/gender into account. *Environ. Health Prev. Med.* 25, 75. doi:10.1186/s12199-020-00915-z

Transportation Research Board and Institute of Medicine (2005). *Does the built environment influence physical activity? Examining the evidence. Special report 282*. Washington, DC: National Academies Press.

Wei, Y. D., Xiao, W., Wen, M., and Wei, R. (2016). Walkability, land use and physical activity. *Sustainability* 8, 65. doi:10.3390/su8010065

World Health Organization (2010). Global recommendations on physical activity for health. Available at: https://www.who.int/publications/i/item/9789241599979 (Accessed January 25, 2024).

Zhang, T., and Huang, B. (2018). Local retail food environment and consumption of fruit and vegetable among adults in Hong Kong. *Int. J. Environ. Res. Public Health* 15, 2247. doi:10.3390/ijerph15102247

Zhang, T., Huang, B., Wong, H., Wong, S.Y.-S., and Chung, R.Y.-N. (2022). Built environment and physical activity among adults in Hong Kong: role of public leisure facilities and street centrality. *Land* 11, 243. doi:10.3390/land11020243

Zhong, J., Liu, W., Niu, B., Lin, X., and Deng, Y. (2022). Role of built environments on physical activity and health promotion: a review and policy insights. *Front. Public Health* 10, 950348. doi:10.3389/fpubh.2022.950348