

Neighborhood Connectedness through Physical-Spatial Dimensions: A Case Study of Communities Near Eastern Industrial Estates in Thailand

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ABSTRACT

Neighborhood connectedness is a key dimension of community well-being and resilience, yet prior research has focused largely on social ties while under examining the role of physical–spatial environments. Drawing on place attachment theory, this study investigates how spatial features shape neighborhood connectedness in the context of urban transformation near a major industrial estate in eastern Thailand. Data were collected from 411 residents across four neighborhoods, categorized as long-established “old” communities and recently developed “new” ones. A second-order confirmatory factor analysis was employed to develop and validate a multidimensional model of connectedness, comprising proximal facilities, pedestrian friendliness, vibrancy, pleasantness, road network, and crime and safety. Results show that the overall model is robust across both old and new neighborhoods, indicating that fundamental links between physical environments and place bonding persist despite differences in settlement history and morphology. However, pedestrian infrastructure demonstrated a context-sensitive role: In new, high-density neighborhoods, walkability was more critical for fostering connectedness than in older neighborhoods with long-standing social ties. These findings advance theoretical understanding by positioning physical–spatial attributes as integral to place attachment while demonstrating their context-dependent effects. The validated model underscores how planning and design practices actively shape neighborhood connectedness, provides a transferable framework for comparative research, and offers practical guidance for planners and designers seeking to foster resilient, connected communities through context-sensitive spatial interventions.

Keywords: neighborhood connectedness, place bonding, industrial estate neighborhood, second-order confirmatory factor analysis, measurement invariance

INTRODUCTION

Neighborhoods are more than physical locations; they are lived spaces where everyday routines, social networks, and personal histories converge. Daily life is embedded in a social fabric shaped by household structures, kinship ties, cultural traditions, and patterns of interaction among residents. These social dynamics are expressed and reinforced through the neighborhood's physical form (Anton & Lawrence, 2014; Atkinson, 2015; Tkach et al., 2024), including housing, public spaces, and infrastructure, which influence how people live, interact, and feel connected to their place (Carmona, 2019; Gehl, 2010; Mouratidis, 2021; Relph, 1976).

In contemporary contexts, neighborhood life is increasingly shaped by mobility, globalization, technological change, and economic restructuring. The shift from agricultural to industrial and post-industrial economies, the growth of high-density housing, and rapid urban transformation have altered both the spatial (Pinkster, 2016; Wilson & Flint, 2024; Yue et al., 2016) and social (Atkinson, 2015; Milligan, 2003; van Beckhoven & van Kempen, 2003) dynamics of local communities. These changes raise important questions about how the physical and spatial characteristics of neighborhoods shape people's connections to place, and whether such bonds endure in the face of substantial transformation.

Urban planners and designers have long recognized the importance of livable neighborhoods in fostering positive people-place relationships that enhance individual well-being and quality of life (Chan & Li, 2022; Gehl, 2010; Manzo & Desanto, 2021; Mooney, 2009; Mouratidis, 2021; Woolever, 1992), strengthen social cohesion, community engagement, and urban resilience (Anton and Lawrence, 2014; Dang, et al., 2022; Song & Soopramaniana, 2019). Much of this vitality arises from the relationship between people and the places they inhabit (Gehl, 2010; Relph, 1976). The literature addresses people-place connections from multiple perspectives, including social ties and belonging (Kim & Kaplan, 2004; Madgin, 2016; Poortinga et al., 2017; Tkach et al., 2024), psychological constructs such as place attachment (Clarke et al., 2018; Hidalgo & Hernández, 2001; Lewicka, 2011; Scannell &

Gifford, 2010), and perceptions of environmental attributes (Carmona, 2019; Chan et al., 2021; Janjamlah & Kaewli, 2020; Westerholt et al., 2022). However, the physical-spatial dimension within place bonding remains underrepresented in empirical research. Existing studies often privilege social interaction and symbolic meaning, treating physical form as a backdrop rather than an integral component of connectedness (Mooney, 2009; Wilkerson et al., 2012; Zahnow, 2024). As Lewicka (2011) notes, the physical nature of places plays a crucial role in shaping residents' affective, cognitive, and behavioral engagement, yet it is frequently overshadowed by social interpretations.

This study addresses this gap by conceptualizing neighborhood connectedness as a form of personal bonding intrinsically linked to physical and spatial characteristics, not solely as a product of social relationships or psychological processes. It examines how physical form and spatial use patterns influence residents' sense of connection to their surroundings. The research is situated in Thailand's eastern industrial corridor, where decades of industrial expansion have produced two contrasting neighborhood types. The first are long-established "old" neighborhoods, characterized by stable settlement patterns and community continuity. The second are newer, denser, mixed-use neighborhoods that developed in response to industrial growth. This contrast offers a natural laboratory for examining whether the underlying structure of neighborhood connectedness, shaped by the interaction between the physical environment and human experience, remains consistent across distinct spatial and developmental contexts.

Across existing perspectives, physical-spatial attributes are either treated in isolation from the psychological processes that underpin attachment or are subsumed under social interpretations. This has resulted in a fragmented understanding of how built form, spatial configuration, and environmental quality interact with affective, cognitive, and behavioral processes to shape neighborhood connectedness. To address this, the present study proposes a differentiated perspective that directly integrates the physical-spatial dimension into the conceptualization and measurement of neighborhood connectedness, enabling a more

practice-oriented framework for urban design and planning. Accordingly, the research asks: *What are the key physical–spatial dimensions that influence neighborhood connectedness, and do these dimensions operate consistently across two distinct neighborhood types within the context of urban transformation?*

Neighborhood Connectedness

Place attachment is defined as the affective bond between individuals and specific settings, encompassing emotional, cognitive, and behavioral dimensions (Hidalgo & Hernandez, 2001; Scannell & Gifford, 2010). Building on this concept, neighborhood connectedness can be understood as a multifaceted construct shaped by both social and physical characteristics of place, involving affective, cognitive, and behavioral processes (Hidalgo & Hernández, 2001; Lewicka, 2011; Relph, 1976). In particular, neighborhood connectedness emphasizes interpersonal trust, reciprocity, and collective identity within the spatial boundaries of a neighborhood (Chan & Li, 2022; Poortinga et al., 2017;). Both place attachment and neighborhood connectedness are associated with well-being, social cohesion, and resilience (Dang et al., 2022; Wilson & Flint, 2024).

Previous Approaches to Physically-Oriented Studies in Neighborhood Connectedness

Three major conceptual approaches have shaped research on neighborhood connectedness. *The first approach* emphasizes the significance of tangible spatial characteristics in shaping people–place relationships. This perspective recognizes that urban form, such as city shape, block structure, density, and land-use patterns, influences spatial behavior. Much of this research has been conducted at the macro level through urban morphological analysis, often supported by advanced tools and technologies such as Geographic Information System (GIS) analysis, data visualization, and machine learning techniques (Prasertsuk & Busayarat, 2022; Srivanit, 2018; Summaniti & Summaniti, 2017; Tochaiwat & Pultawee, 2024). In addition, the Space Syntax approach employs spatial configuration metrics, such as integration and choice, to explain how urban layout shapes

movement patterns, encounter potential, and spatial familiarity (Santad, 2005; Shu & Lin, 2020; Suvannadabha et al., 2022). At the micro scale, research has examined how spatial behaviors—such as everyday interaction and activity (Cerin et al., 2009; Janpathompong et al., 2022; Mouratidis, 2021;), opportunities for social encounter and place satisfaction (Carmona, 2019; Gehl, 2010), and perceptions of safety and comfort (French et al., 2014; Mouratidis, 2021; Zeng et al., 2023)—are shaped by urban elements including street connectivity, pedestrian infrastructure, and mixed-use environments. These studies typically assess the quality of the built environment, highlighting how well-designed and accessible urban settings can foster social life and neighborhood connectedness. However, many such studies assess environments largely through functional, satisfaction, or perceptual lenses without integrating the affective, cognitive, and behavioral dimensions of attachment. As a result, measures of walkability or amenity proximity may capture patterns of use but often do not explain the depth of emotional or identity-based bonds residents develop with their neighborhoods.

The second approach emphasizes the role of interpersonal relationships, shared histories, and symbolic associations in creating meaningful connections to place (Atkinson, 2015; Hidalgo & Hernández, 2001). Here, neighborhood connectedness is understood as emerging primarily from social interactions and cultural meanings rather than from the physical form itself. Although these studies often acknowledge that social and physical dimensions are interrelated, they tend to privilege the social dimension, with the physical environment treated as a secondary or supporting factor (Atkinson, 2015; Milligan, 2003; Zahnw, 2024). In this framing, the physical attributes of a neighborhood are interpreted primarily through the values and meanings attached by its residents, rather than being examined for their direct role in fostering attachment. This emphasis has involved limited exploration of how specific spatial configurations actively contribute to place bonding. Furthermore, common survey measures within this tradition often assess general sentiment (e.g., “I would be sorry to leave this neighborhood”) without explicit reference to environmental form (Boley et al., 2021; Ruiz et

al., 2014), which makes it difficult to translate findings into actionable design and planning strategies.

The third approach distinguishes between the physical and social dimensions of place, recognizing that each serves different psychological and functional roles in the attachment process (Lewicka, 2011; Mooney, 2009). Constructs such as place dependence and place identity are central to this view. Place dependence relates to the functional qualities of the built or natural environment that support individual goals and activities (Hidalgo & Hernandez, 2001; Scannell & Gifford, 2010), while place identity reflects the extent to which individuals incorporate specific places into their self-concept, as in the statement, “This neighborhood is part of who I am” (Ruiz et al., 2014). Studies in this tradition have concentrated on features such as usability of spatial elements, availability of public spaces and amenities, walkability, street connectivity, safety, and proximity to desired services (Appelhans et al., 2024; Janjamlah & Kaewlai, 2020; Mouratidis, 2021; Wilkerson et al., 2012). Emotional bonding is also addressed, emphasizing feelings of belonging and identity, such as being at home, reluctance to leave, and the desire to return (Anton & Lawrence, 2014; Kim & Kaplan, 2004). While this approach differentiates between physical and social influences, it often examines the physical dimension from a utilitarian standpoint and focuses on place-specific experiences. This can limit generalization and application to broader urban design practice.

Neighborhood Connectedness Dimension

In this study, neighborhood connectedness is conceptualized as **a form of physical connectedness** that directly links built environment characteristics to place attachment. While place attachment encompasses affective, cognitive, and behavioral bonds between individuals and meaningful locations (Hidalgo & Hernández, 2001; Scannell & Gifford, 2010), this

conceptualization highlights the role of tangible spatial characteristics in shaping those bonds. Both direct affordances that enable activities, movement, and social encounters, as well as indirect cues that influence perceptions of surroundings, were incorporated in the operationalization of connectedness.

To establish a robust foundation, indicators were generated through a review of established frameworks on neighborhood quality and connectedness. These include multidimensional accounts of neighborhood attributes. Gocer et al. (2023) identify six primary attributes of neighborhoods that relate to quality of life: urban green and blue spaces, amenities, housing quality, physical environment, accessibility and urban mobility, and socio-economic environment. French et al. (2014) identify features directly linked to neighborhood connectedness, including land-use mix (such as shops, services, and transport accessibility), street connectivity, pedestrian and cycling infrastructure, greenery, design coherence, and traffic- and crime-related safety.

Mouratidis (2021) similarly emphasizes accessibility, mobility, aesthetics, and safety in linking urban form with quality of life. Jozwiak (2024) extends these insights by highlighting functional-spatial change features that capture both tangible and experiential qualities of urban form, including spatial structure, aesthetics, non-visual aspects (such as sound and smell), semantics (symbolism and identity), and operational management (including cleanliness and maintenance). Together, these perspectives provide a comprehensive foundation for defining and operationalizing the physical-spatial dimensions of neighborhood connectedness, capturing the diverse ways spatial form and quality shape residents' experiences and attachment. Building on this foundation, 20 physical-spatial indicators were identified to represent the observable and perceptible characteristics of neighborhoods, as summarized in Table 1.

Table 1*Summary of Physical–Spatial Indicators of Neighborhood Connectedness*

Identified indicators	Description
House clustering	The arrangement and density of housing influence visibility, informal surveillance, and opportunities for social interaction. Compact residential patterns enhance accessibility to neighbors and shared facilities (Gocer et al., 2023; Jóźwik, 2024).
Shared spaces	The presence of communal areas supports functional use, social cohesion, and casual encounters between residents. Such spaces reflect amenities provision, are part of land-use diversity (French et al., 2014), and represent functional capabilities that enable social activity (Jozwik, 2024).
Daily life places	Everyday destinations, such as cafés, markets, and small shops, meet routine needs and foster habitual social contact, reinforcing attachment through repeated exposure (French et al., 2014; Gocer et al., 2023) and functional capabilities supporting daily activities (Jozwik, 2024).
Transit nodes	Access to public transportation hubs improves mobility, expands access to services, and encourages community participation. This reflects transport and urban mobility (French et al., 2014; Gocer et al., 2023; Jozwik, 2024; Mouratidis, 2021).
Various services	A diversity of local services increases convenience, reduces travel needs, and enhances neighborhood self-sufficiency. This is part of land-use diversity (French et al., 2014), the availability of amenities (Gocer et al., 2023), and functional capabilities that support resident needs (Jozwik, 2024).
Walkable paths	Well-maintained pedestrian paths enable active mobility, reduce car dependency, and promote incidental encounters. This aligns with walking and cycling infrastructure (French et al., 2014), accessibility and mobility (Gocer et al., 2023; Mouratidis, 2021), and functional capabilities supporting movement (Jozwik, 2024).
Walkway networks	A connected pedestrian network improves navigation, accessibility, and neighborhood legibility. It reflects street connectivity (French et al., 2014), accessibility and mobility (Gocer et al., 2023; Mouratidis, 2021), and spatial structure facilitating efficient movement (Jozwik, 2024).
Safety walkways	Safe pedestrian routes, with adequate lighting and clear sightlines, encourage walking and enhance perceived security. This links to traffic- and crime-related safety (French et al., 2014), physical environment quality (Gocer et al., 2023; Mouratidis, 2021), and operational management such as maintenance and cleanliness (Jozwik, 2024).
Variety of shops	A mix of commercial outlets fosters vibrancy, provides daily conveniences, and supports economic vitality. This reflects land-use mix (French et al., 2014), amenities for social and economic life (Gocer et al., 2023), and functional capabilities enabling diverse activities (Jozwik, 2024).
Lively areas	Areas with visible street activity and social engagement enhance perceptions of vibrancy and vitality. This relates to aesthetic qualities and active street life (French et al., 2014; Mouratidis, 2021), a socio-economic environment that supports public life (Gocer et al., 2023), and semantics conveying identity and meaning (Jozwik, 2024).

Table 1 (Continued)

Identified indicators	Description
Meeting places	Accessible spaces for intentional or spontaneous gatherings strengthen community bonds. This is part of public space in land-use mix (French et al., 2014), amenities for interaction (Gocer et al., 2023), and functional capabilities enabling social use (Jozwik, 2024).
Greenery	Vegetation enhances environmental comfort, visual appeal, and mental well-being. It corresponds to qualities such as greenery (French et al., 2014), and urban green and blue spaces (Gocer et al., 2023).
Aesthetic buildings	Visually appealing and well-designed architecture contributes to place identity and pride. This reflects aesthetic qualities and design coherence (French et al., 2014; Mouratidis, 2021), and housing quality and physical environment (Gocer et al., 2023), and aesthetics (Jozwik, 2024).
Close to roads	Proximity to vehicular roads increases accessibility for goods, services, and mobility. This falls under transport accessibility (French et al., 2014), accessibility and urban mobility (Gocer et al., 2023; Mouratidis, 2021), and spatial structure for connectivity (Jozwik, 2024).
Many routes	A variety of road connections increases route choice and flexibility in movement. This relates to street connectivity (French et al., 2014), accessibility and urban mobility (Gocer et al., 2023; Mouratidis, 2021), and spatial structure supporting circulation (Jozwik, 2024).
Accessible by car	Ease of vehicle access supports convenience for travel, deliveries, and commuting. This aligns with transport accessibility (French et al., 2014), accessibility and urban mobility (Gocer et al., 2023; Mouratidis, 2021), and functional capabilities for mobility (Jozwik, 2024).
Safe at night	Nighttime safety, supported by lighting and visibility, reduces fear of crime and promotes outdoor use after dark. This links to traffic- and crime-related safety (French et al., 2014; Mouratidis, 2021) and non-visual aspects affecting comfort (Jozwik, 2024).
Neighborhood surveillance	Organized surveillance or monitoring increases perceived and actual safety, reinforcing community vigilance. This relates to traffic- and crime-related safety (French et al., 2014; Mouratidis, 2021).
Property conflicts and disputes	A lack of disputes over space use conditions that can lead to conflicts, such as poorly lit areas, neglected public spaces, and unclear territorial boundaries. This aspect aligns with the “crime- and safety-related” category (French et al., 2014; Gocer et al., 2023) and “operational management” considerations (Jozwik, 2024).
High-risk congregation spaces	Gatherings of unlawful activities, including drug-related networks, antisocial behavior, or violent group interactions. This aspect corresponds to the “crime- and safety-related” category (French et al., 2014; Gocer et al., 2023) and relates to “operational management” concerns (Jozwik, 2024).

Study Context and Neighborhood Classification

This study was conducted in four neighborhoods located around the industrial estate in the eastern region of Thailand (Figure 1). Over the past four decades, rapid industrial development has significantly altered the physical and social landscape of surrounding areas. Once primarily composed of traditional agricultural communities, these areas have undergone extensive urbanization, driven by the sustained expansion of industrial zones and the influx of labor migrants from across the country. As shown in Figure 2, the industrial estate expanded in four distinct phases (1990, 2000, 2010, and 2020), each accompanied by corresponding urban growth in surrounding areas. The motorway constructed in the early 2000s further accelerated development by increasing accessibility.

Classification of Neighborhoods. These changes have resulted in the emergence of two distinct neighborhood typologies: (1) *new neighborhoods*, which have been urbanized for several decades and are now highly integrated into the urban fabric, and (2) *old neighborhoods*, which have only recently begun transitioning as a result of the industrial estate's outward expansion. To capture the variations in urbanization and built form, a multi-stage sampling method was used to select four neighborhoods for study, with two drawn from

each category (Figure 2). Each neighborhood was defined by a 600-meter radius around its central node to maintain consistency in spatial analysis. These distinctions were essential for the subsequent comparative analysis of physical-spatial factors in neighborhood connectedness.

Neighborhood Urbanity Assessment. The degree of being urban in order to compare places based on how urbanized they are was assessed through objective physical measures encompassing: land use mix (residential, retail, services, recreation, agriculture, and vacant land), Residential density (number of dwelling units), commercial activity (number of business-related buildings), and connectivity (intersection density of the street network with three or more connecting nodes). These measures were used to systematically characterize the built environment of each neighborhood, forming the basis for comparing their physical transformations and their potential influence on neighborhood connectedness.

Comparative Physical Characteristics. As shown in Table 2, the new neighborhoods display markedly higher residential densities and a predominance of high-rise housing types, such as apartments and condominiums. Townhouses and shophouses are also more numerous in these new areas. In contrast, the old neighborhoods retain more traditional land uses, including agriculture and recreation, and are characterized by a lower building density and simpler housing forms.

Figure 1

Location of the Industrial Estate in the Eastern Region of Thailand

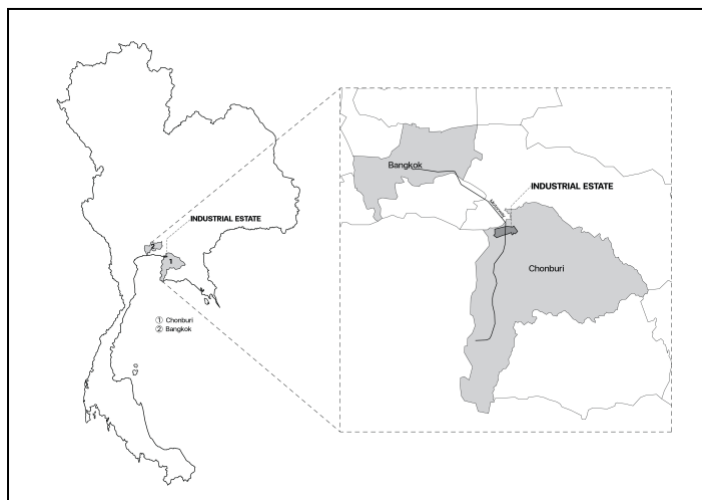


Figure 2
Expansion of the Industrial Estate and its Surrounding Neighborhoods

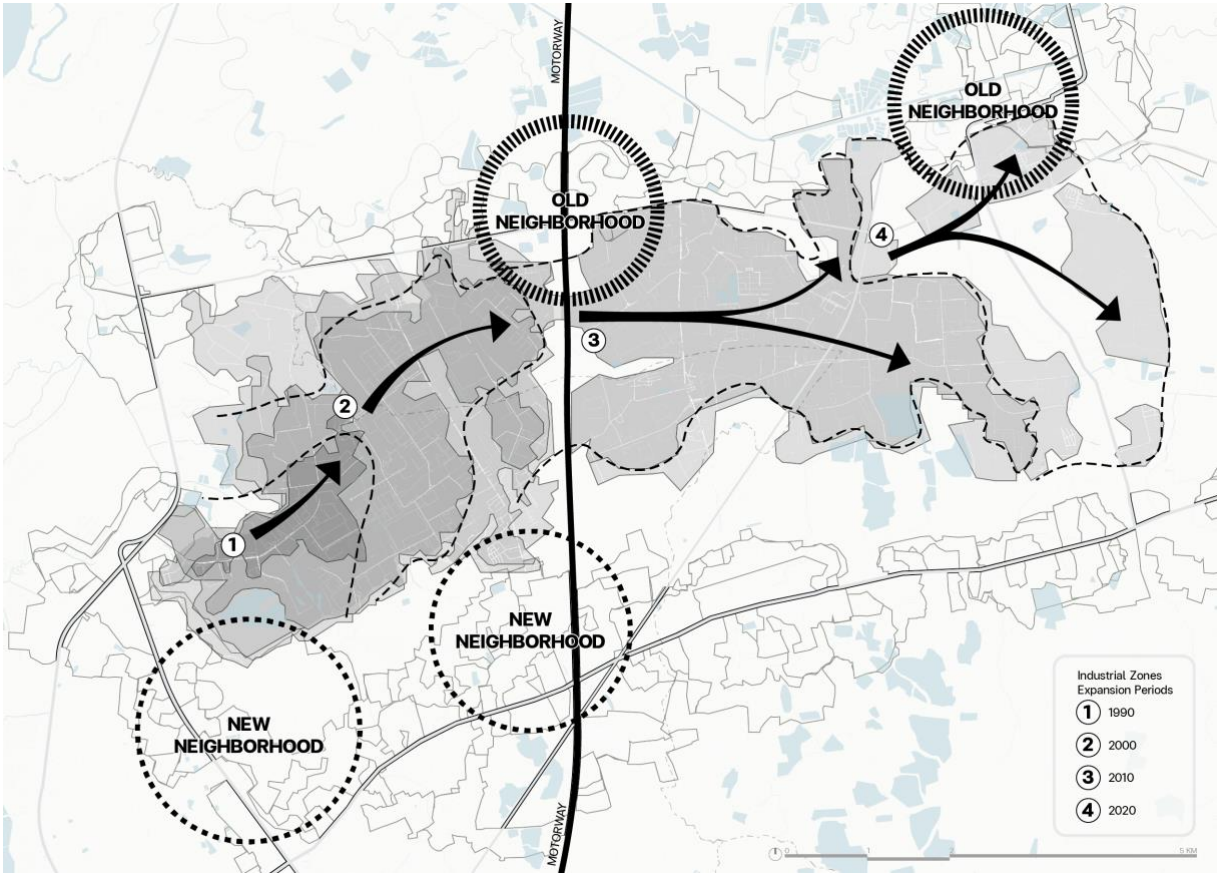


Table 2
Comparative Physical Characteristics of New and Old Neighborhoods

Characteristics	New Neighborhoods	Old Neighborhoods
Total Residential Units	20,209	5,662
- Apartment/Condominium	13,757	4,659
- Detached Houses	1,394	792
- Townhouses	3,398	71
- Shophouses	1,281	726
Commercial (retail, food, markets)	1,020	1,024
Social Services (health, welfare)	98	70
Recreation (culture, leisure)	11	34
Agricultural Use	3	93
Vacant Land	8	2

These differences underscore the influence of urban transformation on neighborhoods. New neighborhoods, developed in response to market-oriented housing demand and proximity to industrial employment, exhibit highly urbanized characteristics. In contrast, old neighborhoods, although beginning to urbanize, still retain elements of their pre-urban identity.

METHODS

Participants

The study sample consisted of residents aged 18 years and older living in the surroundings of industrial estates (Table 3). A stratified sampling approach was employed to ensure representation from both “old” and “new” neighborhoods. Four neighborhoods were selected, comprising two classified as “old” and two as “new,” based on their spatial characteristics and degree of urban transformation. Within each neighborhood, central nodes such as local markets, community centers, and public transit stops were identified as data collection points. These locations were randomly assigned to eight trained research assistants for survey administration. This approach facilitated broad demographic coverage; however, it may have underrepresented certain groups, such as elderly residents with limited mobility who were less likely to be present in public spaces during survey hours. Data were collected through face-to-face interviews using structured questionnaires. In total, 411 residents participated in the survey, including 190 from new neighborhoods and 221 from old neighborhoods.

Scale Measurement

Neighborhood connectedness was defined as the affective bond between people and their local environments. This study draws upon the conceptualization of place attachment as an often unconscious bond between individuals and their environments, which typically becomes evident only when the individual experiences a disruption or separation from that place. As

Cheng and Chou (2015) also pointed out, place bonding is subject to change when a place is unavailable. As proposed by Hidalgo and Hernandez (2001), this latent attachment can be revealed by asking individuals to reflect on hypothetical scenarios involving relocation. Their scale includes items such as “I would be sorry to move out of my house/neighborhood/city without the people I live with,” where the expression of regret is used to elicit latent emotional ties. In line with this approach, the present study adapts this conceptual framework to develop items that capture physical–spatial aspects of neighborhood connectedness. Specifically, participants were asked to indicate the degree to which they would “feel regretful or reluctant to leave their neighborhood under various physical-spatial conditions,” thereby allowing these affective bonds to manifest in measurable form.

Item development followed a mixed approach. A review of validated instruments informed the initial 20-item pool, with several items adapted from existing scales, including French et al. (2014) for perceived neighborhood design features, Mouratidis (2021) for linking urban form with quality of life, Jozwiak (2024) for functional–spatial change dimensions, and Gocer, et al. (2023) for multidimensional attributes of neighborhood quality. As described in the section “Neighborhood Connectedness Dimension,” an initial pool of 20 items representing the hypothesized indicators of neighborhood connectedness was developed to capture key physical characteristics of the built environment. The items were adapted to ensure relevance to the Thai context, and a pilot study involving 51 residents was conducted to assess cultural appropriateness and clarity. Exploratory factor analysis (EFA) using principal axis factoring with varimax rotation identified six components that accounted for 74.91% of the total variance, with an overall internal consistency of Cronbach’s $\alpha = 0.80$. The six components were: **Proximal Facilities** (5 items), **Pedestrian Friendliness** (3 items), **Vibrancy** (3 items), **Pleasantness** (2 items), **Road Network** (3 items), and **Crime and Safety** (4 items).

To strengthen content validity, the scale and EFA results were reviewed by five experts in urban design and planning. For conceptual consistency, two hypothesized items originally classified under the physical–spatial domain, but assessing

perceptions of social order, Property Conflicts and Disputes and High-risk Congregation Spaces were removed from the physical-spatial domain, as they aligned more closely with social rather than physical aspects. While these items are important to neighborhood connectedness, they primarily capture perceptions of social order rather than measurable attributes of the physical environment. Moreover, the disputes over space use conditions and the gatherings of unlawful activities are shaped by a complex interplay of social, economic, and behavioral factors, making them difficult to address directly through physical design interventions and challenging to operationalize as objective physical environment indicators. The final instrument employed a 6-point Likert scale (1 = strongly disagree to 6 = strongly agree), intentionally omitting a neutral midpoint to encourage respondents to take a position. This format was selected to minimize central tendency bias and improve the scale's sensitivity in capturing subtle differences in residents' emotional connectedness across neighborhoods.

In addition to the main scale, the questionnaire collected basic socio-demographic data, including age, education, monthly income, length of residence, number of close social ties (friends or relatives), place of birth, housing type, household composition, and home ownership status.

Data Analysis

To uncover the underlying structure of neighborhood connectedness and to empirically validate its multidimensional nature, exploratory and confirmatory factor analysis allowed us to reduce a broad set of spatial indicators into coherent latent dimensions, thereby aligning measurement with theory. The analysis proceeded in three stages:

Stage 1: Exploratory Factor Analysis

EFA was used to identify the underlying factor structure of the initial 20-item pool and to reduce items to a parsimonious set representing 6 distinct physical-spatial dimensions. Principal axis factoring with varimax rotation was applied to determine the number of components and the allocation of items to factors, guided by

eigenvalues, scree plot inspection, and theoretical interpretability.

Stage 2 Second-Order Confirmatory Factor Analysis

A second-order CFA was conducted to verify whether the six first-order factors identified through EFA could be represented as dimensions of an overarching latent construct, consistent with the theoretical framework of neighborhood connectedness. The model specified six first-order factors: **F1: Proximal Facilities** (5 items); **F2: Pedestrian Friendliness** (3 items); **F3: Vibrancy** (3 items); **F4: Pleasantness** (2 items); **F5: Road Network** (3 items); and **F6: Crime and Safety** (2 items), loading onto a single second-order latent variable representing overall neighborhood connectedness. This stage aimed to validate the theoretical structure, assess construct coherence, and confirm the appropriateness of modeling neighborhood connectedness as a higher-order construct.

Stage 3: Measurement Invariance Testing

To examine whether the structure of neighborhood connectedness was consistent across different types of neighborhoods (new vs. old), second-order measurement invariance testing was performed. Following the recommendations of Chen et al. (2005), Dimitrov (2010) and Rusnev et al. (2018), for partial invariance testing, testing here proceeded through a hierarchical sequence: (1) baseline model, M0; (2) first-order factor loading invariant, M1; (3) first- and second-order factor loadings invariant, M2; (4) M2P= partial invariance of second-order factor loadings, M2P; (5) item intercepts invariant, M3; (6) latent intercepts invariant, M4; (7) items residual variances invariant, M5; and (8) latent residual variances invariant, M6.

Model fit was assessed using widely accepted indices: Comparative Fit Index (CFI): $\geq .90$ acceptable, $\geq .95$ good, Tucker-Lewis Index (TLI): $\geq .90$ acceptable, $\geq .95$ good, Root Mean Square Error of Approximation (RMSEA): $\leq .06$ good, Standardized Root Mean Square Residual (SRMR): $\leq .08$ good (Chen et al., 2005). Changes in fit between nested models were evaluated using the following criteria: $\Delta CFI \leq .010$ to $.020$, $\Delta RMSEA \leq .015$ to $.030$, $\Delta SRMR \leq .015$ (Chen et al, 2005; Cheung & Rensvold,

2002; Rutkowski & Svetina, 2014). Descriptive statistics (means and standard deviations) and Pearson correlations were calculated separately for old and new neighborhoods (Table 2). The software Jamovi (version 2.3.28) was used for all statistical analyses.

RESULTS

Demographic Characteristics of Participants

A total of 411 residents from 4 neighborhoods participated in the study, comprising 190

individuals from new neighborhoods and 221 from old neighborhoods. Table 3 presents a comparison of demographic variables across the two groups.

The results reveal that residents in old neighborhoods tend to be slightly older, have lived in the area longer, and are more likely to be homeowners. In contrast, new neighborhoods exhibit a more transient, diverse residential population, with more renters and residents living in high-density housing types such as apartments and condominiums. Social networks also differed, with old neighborhood residents reporting a higher average number of friends and relatives.

Table 3
Demographic Characteristics of Participants by Neighborhood Type

	New Neighborhoods (n=190)	Old Neighborhoods (n=221)
Average Age (years)	41.99 (14.08)	43.62 (13.63)
Secondary Education or Higher (%)	44.80	40.70
Average Length of Residence (years)	19.76 (20.62)	24.45 (22.08)
Monthly Income Over 20,000 Baht (%)	32.60	27.60
Average Number of Friends (SD)	6.62 (12.05)	15.61 (27.43)
Average Number of Relatives (SD)	3.54 (6.59)	6.45 (10.81)
Percentage of Participants Born in this City (%)	50.50	61.10
Housing Type		
Apartment	68 (35.80)	22 (10.00)
Condominium	50 (26.30)	15 (6.80)
House or Townhouse	50 (26.30)	142 (64.30)
Commercial Building	22 (11.60)	42 (19.00)
Household Composition (Co-residents)		
Extended Family	8 (4.20)	77 (34.80)
Partner/Spouse	68 (35.80)	76 (34.40)
Friends	86 (45.20)	39 (17.70)
Living Alone	28 (14.70)	29 (13.10)
Home Ownership Type		
Renting	79 (41.60)	67 (30.30)
Owned	82 (43.20)	128 (57.90)
Living with Relatives (No rent)	29 (15.30)	26 (11.80)

Note. (Values are presented as means (SD) or percentages)

Second-Order Confirmatory Factor Analysis (CFA) of Neighborhood Connectedness

A second-order CFA was conducted to validate the hypothesized model of **neighborhood connectedness**, consisting of 6 first-order latent constructs with a total of 18 items (Table 4). The model showed a good overall fit to the data.

The results indicated that the hypothesized model demonstrated a good overall fit to the data: $\chi^2(122) = 307, p < .001$; RMSEA = .061; SRMR = .067; CFI = .953; TLI = .941. The analysis of second-order factor loadings confirmed that the neighborhood connectedness construct was composed of six sub-dimensions, all of which loaded significantly onto the higher-order factor ($p < .001$). Among these, F1:

Proximal Facilities and F3: Vibrancy exhibited the highest standardized loadings, followed by F5: Road Network and F6: Crime and Safety. The dimensions with the lowest standardized loadings were F2: Pedestrian Friendliness and F4: Pleasantness. In substantive terms, these model fit indices indicate that the proposed theoretical structure, where multiple sub-dimensions are combined to represent an overarching connectedness construct, aligns well with the observed data.

At the first-order level, all 18 observed indicators significantly loaded onto their respective sub-dimensions ($p < .001$), with standardized factor loadings ranging from .56 to .88. These findings support the construct validity of the measurement model and affirm that each sub-dimension is a meaningful and statistically reliable component of neighborhood connectedness.

Table 4
Standardized Factor Loadings and Descriptive Statistics

Factors	Survey items: How much you would be sorry or think about leaving if ...	Coding	Mean	SD	Loading (β)	R ²
F1 Proximal Facilities					.88***	.77
C1	... if your residence was no longer located in a cluster or close to other houses?	House clustering	4.70	1.21	.67***	.45
C2	... if your residence was no longer near shared open spaces used with neighbors?	Shared space	4.67	1.38	.78***	.60
C3	... if you could no longer access essential daily destinations (e.g., shops, restaurants, services, fitness centers, transportation hubs) within a 15-minute walk?	Daily life places	4.68	1.35	.75***	.55
C4	... if public transportation access (e.g., bus stops, van stations, motorbike taxis) was no longer easily reachable from your home?	Transit nodes	4.70	1.40	.77***	.60
C5	... if your residence was no longer near essential services such as a post office, bank, electricity/water offices, or a gas station?	Various services	4.80	1.32	.75***	.56

Table 4 (Continued)

Factors	Survey items: How much you would be sorry or think about leaving if ...	Coding	Mean	SD	Loading (β)	R ²
F2 Pedestrian Friendliness					.29***	.08
C6	... if there were no longer pedestrian pathways that allow you to run errands in your neighborhood?	Walkable paths	3.11	1.40	.61***	.37
C7	... if the pedestrian walkways in your area were no longer well-connected?	Walkway network	2.52	1.33	.61***	.37
C8	... if the pedestrian walkways in your area were no longer protected from traffic (e.g., separated from roads, barriers in place)?	Safety walkways	2.95	1.39	.79***	.64
F3 Vibrancy					.88***	.77
C9	... if your neighborhood no longer had a variety of shops that support and enhance daily life?	Variety of shops	4.40	1.44	.76***	.58
C10	... if your neighborhood no longer had places and services that make the area vibrant and full of people?	Lively areas	4.70	1.20	.88***	.77
C11	... if your residence was no longer close to places where you can meet and interact with others?	Meeting places	5.00	1.30	.67***	.45
F4 Pleasantness					.24***	.06
C12	... if your neighborhood no longer had many trees and green spaces, creating a shady and pleasant atmosphere?	Greenery	4.81	1.31	.76***	.58
C13	... if the buildings and houses in your neighborhood were no longer visually appealing and well-maintained?	Aesthetic buildings	5.30	1.15	.84***	.71
F5 Road Network					.62***	.38
C14	... if your residence was no longer near a highway, main road, or major intersection?	Close to road	4.73	1.46	.58***	.33
C15	... if you no longer had multiple alternative routes to reach different places besides the main roads?	Many routes	4.89	1.25	.70***	.49
C16	... if your residence was no longer easily accessible by car (i.e., if it was located in a narrow or deep alley)?	Accessible by car	4.27	1.56	.60***	.36

Table 4 (Continued)

Factors	Survey items: How much you would be sorry or think about leaving if ...	Coding	Mean	SD	Loading (β)	R ²
F6 Crime and Safety					.51***	.26
C17	... if outdoor spaces in your neighborhood no longer felt safe at night?	Safe at night	4.64	1.45	.56***	.31
C18	... if the building orientation and street layout no longer allowed for natural surveillance (e.g., residents cannot see public areas from their homes)?	Neighborhood surveillance	4.72	1.39	.73***	.54

Note. ***p<.001

Assessing Model Invariance
Across Urban Transformation
Contexts

To assess the item-level relationships prior to testing for measurement invariance, correlation matrices of the 18 connectedness indicators were computed separately for the old and new neighborhoods (Table 5). To assess the invariance of connectedness model by level of urbanicity, the invariance testing was initiated by fitting the second-order CFA Model of Connectedness in each area separately (not reported). The model demonstrated an acceptable fit in both areas and all factor loadings are significant at 0.01.

To examine the factorial invariance of the second-order factor model of connectedness across two areas, a series of hierarchical model comparisons were tested. Table 6 displays that the pairwise comparisons of nested models provide evidence of invariance across two areas.

Model 0: The baseline invariance, which included no cross-group constraints, demonstrated acceptable model fit, supporting the same factor structure across the two areas (Figure 3). Also Model 1, which tested for metric invariance of the first-order factors, showed an acceptable fit. There was no substantial difference in ΔCFI , $\Delta RMSEA$, and $\Delta SRMR$ in the model compared to Model 0. This indicates that the first-order factor loadings could be considered invariant across areas, suggesting that the strength of

relationships between 18 items and their respective first-order factors was equivalent in both areas. However, for testing equal across groups by constraint all first- and second-order factor loadings in comparison of Model 2 and Model 1, the invariance was not supported. This is supported by the ΔCFI , and $\Delta RMSEA$ values (-.029 and .015), according to the criteria that $\Delta CFI < .01$, $\Delta RMSEA > .15$ indicates lack of invariance (Cheung & Rensvold, 2002). This indicated that at least one of the second-order factor loadings differed between the two areas, suggesting that the construct of Connectedness may have a stronger or weaker effect on certain first-order factors depending on the area.

Given the lack of full invariance in second-order factor loadings, we explored the partial invariance by freeing the loading of F2 (Pedestrian Friendliness) while keeping the rest constrained. Following the consideration of one construct, F2: Pedestrian Friendliness, has a statistically significant MI for the second-order factor loading with MI = 90.969. This adjustment allowed for flexibility in how F2 relates to Connectedness, while still ensuring comparability of the remaining second-order factor loadings. After this modification, M2P, the model fit improved and became statistically equivalent to the M1 model. This result suggests that the loading of the first-order factors, except F2 on the Connectedness construct, is largely stable across the two areas, enabling meaningful cross-group comparisons.

Table 5

Descriptive Statistics and Correlations of New (Under Diagonal) and Old Neighborhoods (Above Diagonal)

	mean	SD	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	mean	SD
C1	4.77	1.23		0.48	0.48	0.47	0.43	0.06	0.02	0.10	0.55	0.57	0.42	0.08	0.16	0.35	0.27	0.10	0.21	0.20	4.64	1.20
C2	4.59	1.50	0.51		0.80	0.68	0.57	0.17	0.03	0.12	0.42	0.56	0.43	0.18	0.12	0.30	0.14	0.22	0.15	0.31	4.74	1.26
C3	4.63	1.43	0.50	0.75		0.67	0.47	0.12	0.02	0.05	0.35	0.56	0.36	0.22	0.16	0.31	0.22	0.23	0.12	0.30	4.72	1.28
C4	4.65	1.51	0.44	0.65	0.64		0.64	0.08	0.08	0.01	0.42	0.58	0.44	0.20	0.15	0.24	0.19	0.17	0.25	0.31	4.75	1.30
C5	4.81	1.32	0.44	0.46	0.46	0.70		0.18	0.14	0.04	0.45	0.53	0.41	0.19	0.15	0.36	0.22	0.19	0.31	0.26	4.79	1.31
C6	2.98	1.53	0.08	0.20	0.19	0.11	0.07		0.33	0.37	0.15	0.18	0.13	0.02	0.16	0.16	0.26	0.13	0.12	0.15	3.23	1.27
C7	2.67	1.42	0.22	0.28	0.29	0.21	0.12	0.55		0.59	0.02	0.07	0.11	0.25	0.32	0.16	0.01	0.01	0.11	0.03	2.38	1.23
C8	3.14	1.43	0.27	0.35	0.24	0.27	0.23	0.33	0.54		0.14	0.08	0.10	0.16	0.22	0.09	0.07	0.00	0.07	0.04	2.78	1.32
C9	4.51	1.49	0.50	0.45	0.41	0.53	0.54	0.24	0.21	0.33		0.69	0.42	0.09	0.10	0.33	0.11	0.04	0.18	0.22	4.31	1.38
C10	4.73	1.26	0.66	0.46	0.49	0.49	0.55	0.12	0.17	0.30	0.74		0.57	0.20	0.24	0.28	0.25	0.16	0.27	0.28	4.68	1.15
C11	5.02	1.27	0.47	0.34	0.33	0.35	0.48	0.17	0.15	0.29	0.54	0.56		0.16	0.19	0.27	0.14	0.14	0.30	0.15	4.98	1.32
C12	4.85	1.26	0.06	0.13	0.01	0.07	0.11	0.13	0.11	0.02	0.10	0.07	0.21		0.68	0.09	0.15	0.02	0.04	0.05	4.78	1.36
C13	5.44	1.04	0.05	0.10	0.11	0.23	0.23	0.06	0.15	0.04	0.19	0.09	0.29	0.58		0.13	0.15	0.02	0.05	0.01	5.18	1.22
C14	5.17	1.25	0.10	0.14	0.18	0.18	0.23	0.07	0.09	0.19	0.22	0.13	0.32	0.03	0.04		0.25	0.34	0.47	0.37	4.34	1.52
C15	5.07	1.20	0.22	0.30	0.36	0.27	0.45	0.13	0.11	0.14	0.35	0.34	0.29	0.18	0.14	0.43		0.46	0.28	0.24	4.73	1.28
C16	4.39	1.59	0.19	0.30	0.23	0.20	0.35	0.21	0.15	0.17	0.22	0.22	0.19	0.26	0.16	0.23	0.55		0.34	0.32	4.16	1.54
C17	4.65	1.36	0.07	0.14	0.12	0.07	0.15	0.04	0.03	0.16	0.04	0.13	0.05	0.07	0.02	0.06	0.21	0.29		0.49	4.63	1.52
C18	4.82	1.35	0.12	0.19	0.18	0.13	0.22	0.08	0.07	0.15	0.14	0.13	0.26	0.07	0.11	0.25	0.33	0.40	0.30		4.64	1.42

Figure 3

Standardized Factor Loadings of the Baseline Invariance across Neighborhood (new/old), all $p < 0.01$



Table 6

Testing for Factorial Invariance of a Second-order Factor Model of Connectedness Across Two Neighborhoods

Model	χ^2	df	CFI	TLI	RMSEA	SRMR	Model Comparison	$\Delta\chi^2$	Δdf	ΔCFI	$\Delta RMSEA$	$\Delta SRMR$
M0	429	244	0.955	0.944	0.061	0.079						
M1	471	256	0.948	0.938	0.064	0.084	M1-M0	42	12	-0.007	0.003	0.005
M2	595	261	0.919	0.905	0.079	0.093	M2-M1	124	5	-0.029	0.015	0.009
M2P (FREE F2)	498	260	0.942	0.932	0.067	0.086	M2P-M1	27	4	-0.006	0.003	0.002
M3	498	260	0.942	0.932	0.067	0.086	M3-M2P	27	4	-0.002	0.003	0.002
M4	527	278	0.940	0.934	0.066	0.088	M4-M3	29	18	-0.007	-0.001	0.002
M5	562	284	0.933	0.928	0.069	0.091	M5-M4	35	6	-0.001	0.003	0.003
M6	584	302	0.932	0.931	0.068	0.094	M6-M5	22	18	-0.007	-0.001	0.003
M7	619	309	0.925	0.926	0.07	0.099	M7-M6	35	7	-0.007	0.002	0.005

Note. M0=baseline model; M1= first-order factor loading invariant; M2= first- and second-order factor loadings invariant; M2P= first- and second-order factor loadings invariant, and partial invariance of second-order factor loadings (free second-order factor loading of F2); M3= first- and second-order factor loadings invariant, partial invariance of second-order factor loadings, and item intercepts invariant; M4= first- and second-order factor loadings invariant, partial invariance of second-order factor loadings, item intercepts, and latent intercepts invariant; M5= first- and second-order factor loadings invariant, partial invariance of second-order factor loadings, item intercepts, latent intercepts, and items residual variances invariant; M6= first- and second-order factor loadings invariant, partial invariance of second-order factor loadings, item intercepts, latent intercepts, items residual variances, and latent residual variances invariant.

After establishing partial second-order factor loading invariance, we tested for item intercept invariance, M3. The results supported invariance at this level. Constraining latent intercepts, M4, to equality across areas did not significantly degrade model fit, supporting latent intercept invariance. Furthermore, imposing equality constraints on item residual variances, M5, yielded a model fit consistent with the previous model, indicating invariance at this level. Finally, M6, testing for latent residual variances invariance revealed that model fit remained acceptable, confirming invariance at this highest level.

The results of this hierarchical invariance testing suggest that the second-order factor model of connectedness is largely invariant across the two areas. While full invariance of second-order factor loadings was not supported, partial invariance was achieved by freeing the factor loading of F2 (Pedestrian Friendliness), which allowed us to establish comparability across

subsequent levels of invariance testing. Beyond this adjustment, the model exhibited strong evidence of invariance in item intercepts, latent intercepts, item residual variances, and latent residual variances. These findings indicate that the connectedness construct is conceptually and statistically comparable between the two areas, allowing for meaningful cross-group comparisons of both factor structure and latent mean differences. Given that the emphasis of the analysis is on factorial structure comparisons rather than average discrepancies, thus this study does not compare the mean values between areas. In practical terms, this means that the same dimensions of connectedness are relevant and interpretable in both old and new neighborhoods, even though the strength of the pedestrian-related factor varies by context. The creation of partial invariance ensures that differences observed are linked to authentic contextual differences rather than measurement errors, reinforcing the robustness of the model for comparative analysis.

Overall, the results provide strong empirical support for the proposed multidimensional structure of neighborhood connectedness and demonstrate its robustness across contrasting urban contexts. The model confirms that connectedness is reliably represented by multiple physical–spatial dimensions, with Proximal Facilities and Vibrancy emerging as the most influential. Importantly, the invariance testing shows that these dimensions are conceptually comparable between old and new neighborhoods, with the exception of pedestrian infrastructure, which plays a more context-dependent role. Together, these findings establish a validated and generalizable measurement model that captures both the stability and contextual sensitivity of neighborhood connectedness, laying the groundwork for subsequent theoretical interpretation and practical application.

DISCUSSION

The present study conceptualizes neighborhood connectedness as a form of personal bonding that is intrinsically tied to the physical–spatial characteristics of the environment and investigates whether varying levels of urbanization produce distinct indicators of connectedness. This approach advances existing theoretical frameworks of place attachment, which have traditionally emphasized the psychological and functional roles of attachment processes (Hidalgo & Hernández, 2001; Lewicka, 2011; Scannell & Gifford, 2010). Much of the prior literature has interpreted neighborhood connectedness predominantly through its social dimension, framing it as a multifaceted bond rooted in interpersonal ties, reciprocity, and shared identity (Chan & Li, 2022; Dang et al., 2022; Poortinga et al., 2017). By contrast, the physical dimension has often been relegated to a secondary, utilitarian perspective, conceptualized as "place dependence," where attachment derives from the functional qualities of the built or natural environment that facilitate personal goals and activities (Kim & Kaplan, 2004; Ruiz et al., 2014).

This study contributes empirical evidence to ongoing theoretical debates by demonstrating

that the built environment is not merely a passive backdrop for social interaction, but an active determinant that jointly shapes attachment processes. Physical–spatial features such as accessibility, walkability, and neighborhood facilities are shown to play central roles in reinforcing emotional bonds and community well-being (Carmona, 2019; French et al., 2014; Mouratidis, 2021). In doing so, the findings extend place attachment theory by integrating physical–spatial attributes as co-constitutive elements of neighborhood connectedness, thereby providing a more comprehensive framework for understanding how urban form influences people–place relationships (Madgin et al., 2016; Westerholt et al., 2022).

The identification of six key dimensions of neighborhood connectedness: Proximal Facilities, Pedestrian Friendliness, Vibrancy, Pleasantness, Road Network, and Crime and Safety, provides empirical support for Lewicka's (2011) argument to broaden the conceptualization of place. While the basic definition of place as a "meaningful location" offers a useful starting point, it remains too general and calls for more nuanced specifications. Earlier scholarship has primarily emphasized place at broad scales, such as neighborhoods, homes, cities, national regions, or continents, without fully addressing the localized meaningfulness that emerges from direct integration of physical–spatial characteristics. Our findings highlight how specific environments such as residential areas, workplaces, recreational grounds, or even virtual and imagined places embody physical attributes that actively shape the experience of place attachment.

The findings of this study provide robust empirical support for the multidimensionality of neighborhood connectedness. Results from the second-order confirmatory factor analysis confirmed that six distinct but interrelated sub-dimensions collectively represent a higher-order construct of neighborhood connectedness. This multidimensional structure underscores the idea that everyday urban form is central to how residents develop emotional bonds with their neighborhoods (Lewicka, 2011; Scannell & Gifford, 2010).

Among these dimensions, Proximal Facilities and Vibrancy emerged as the most influential

contributors. Their prominence highlights the role of access to daily necessities, services, and opportunities for social interaction, as well as the presence of active, mixed-use environments. These findings align with prior research emphasizing that vitality and everyday convenience are fundamental determinants of urban quality of life (Chan & Li, 2022; French et al., 2014). They also resonate with classic perspectives that highlight how mixed land uses and lively street life promote social ties and a collective sense of community (Gehl, 2010; Relph, 1976).

The Road Network dimension demonstrated a moderate contribution to connectedness, reflecting the car-oriented character of neighborhoods surrounding industrial estates. In such contexts, well-connected road systems enhance daily mobility, economic access, and integration with the wider urban network, thereby reinforcing residents' sense of attachment (Carmona, 2019; Wilkerson et al., 2012). Crime and Safety, by contrast, illustrated how physical design features such as lighting, visibility, and natural surveillance interact with social trust to shape residents' perceptions of security. In the study area, this interaction is further reinforced by informal monitoring practices common in Asian communities, highlighting how safety is co-produced by both environmental design and social practices (Hidalgo et al., 2020; Poortinga et al., 2017).

Conversely, Pedestrian Friendliness and Pleasantness exhibited comparatively lower factor loadings. This outcome may reflect weaker cultural expectations for walkability or aesthetic coherence in neighborhoods where pedestrian culture is not deeply embedded and where greenery or visual quality is overshadowed by functional and survival priorities. Nevertheless, the variability of these dimensions across contexts underscores the sensitivity of neighborhood connectedness to differences in urban form (Cerin et al., 2009; Mouratidis, 2021).

Taken together, these findings demonstrate that physical-spatial characteristics are not peripheral but integral to the conceptualization of place attachment. They function both as direct affordances for activity and mobility and as symbolic cues shaping perceptions of safety, comfort, and identity (Kim & Kaplan, 2004; Madgin et al., 2016). The evidence supports

urban form theory by showing that spatial configuration and land-use patterns are central to neighborhood connectedness, particularly in the midst of rapid urban transformation (Manzo & Desanto, 2021; von Wirth et al., 2016). By validating physical-spatial characteristics as measurable and distinct dimensions of connectedness, this study extends existing conceptualizations of place and provides a more practice-oriented framework for urban planning and design.

Partial Invariance in Pedestrian Friendliness

Beyond confirming the expected relationships, the study also revealed context-sensitive insights that refine our understanding of neighborhood connectedness. While all six dimensions contributed meaningfully to the higher-order construct, the Pedestrian Friendliness factor exhibited differential effects across neighborhood types. Measurement invariance testing confirmed that the six-dimensional model of connectedness was robust across both long-established “old” neighborhoods and recently-developed “new” neighborhoods. This consistency underscores the theoretical proposition that fundamental associations between physical environments and community bonding remain valid despite differences in settlement histories and urban morphologies (Chan & Li, 2022; Poortinga et al., 2017; Scannell & Gifford, 2017).

One of the most notable findings concerns the partial invariance of the Pedestrian Friendliness dimension, which functioned differently across the two neighborhood types. New neighborhoods are characterized by higher residential densities and a predominance of compact housing forms, particularly apartments and condominiums (Table 1). These denser, mixed-use environments inherently increase pedestrian flows, making reliance on formalized pedestrian infrastructure, including continuous sidewalks, safe crossings, and well-connected pathways, essential for daily mobility. Demographically, residents in new neighborhoods also tend to be more transient, with shorter average lengths of residence and higher rates of renting (Table 2). These conditions suggest weaker long-term social ties, which means that physical walkability

compensates for the relative absence of established community networks, providing crucial opportunities for everyday encounters and social connectedness.

By contrast, old neighborhoods maintain lower residential densities, more traditional housing types such as detached houses and shophouses, and greater proportions of agricultural and recreational land (Table 1). They are also home to residents who report stronger social networks, with significantly higher averages of close friends (15.6 vs. 6.6) and relatives (6.5 vs. 3.5) compared to their counterparts in new neighborhoods (Table 2). These enduring bonds, cultivated over time through familiarity and shared histories, appear to buffer against deficiencies in formal walkability. As a result, residents' sense of connectedness in these areas is sustained less by pedestrian infrastructure and more by long-standing social ties and informal uses of shared spaces.

This dual finding highlights the context-sensitive role of pedestrian infrastructure. In new neighborhoods, designed under conditions of rapid industrial expansion, well-planned pedestrian systems are indispensable for fostering connectedness, resonating with studies that link walkability to casual encounters and stronger community bonds (Cerin et al., 2009; Gehl, 2010; Mouratidis, 2021). In older neighborhoods, however, connectedness relies more on embedded social capital, where community attachment is reinforced through kinship networks and collective familiarity, even if sidewalks and formal pathways are limited. Theoretically, this suggests that the role of physical affordances in place attachment is contingent on settlement history and the strength of existing social fabrics (Atkinson, 2015; Lewicka, 2011; Manzo et al., 2023). Practically, it underscores that urban design interventions must be tailored: enhancing pedestrian permeability and safety may be most effective in new, high-density neighborhoods, while in older areas, strategies should focus on strengthening the interface between vehicular mobility, shared public spaces, and community activities.

Overall, these results contribute to theory by showing that the physical dimensions of neighborhood connectedness are both universally relevant and locally contingent. While the overarching structure of connectedness holds

across divergent urban settings, the salience of individual dimensions, particularly walkability, varies with neighborhood form and demographic composition. This duality reinforces the importance of adaptable frameworks of place attachment and urban form, acknowledging that while the physical environment is integral to social cohesion, its effects are mediated by context-specific social and spatial conditions.

Practical Implications for Urban Design and Planning

This study demonstrates that neighborhood connectedness depends not only on social ties but also on physical–spatial features that are universally important yet locally contingent. For urban planners and policymakers, the results highlight the need to ensure access to daily facilities and vibrant mixed-use areas, invest in pedestrian infrastructure in new high-density neighborhoods, and strengthen communal spaces and multimodal access in older neighborhoods. Designing for both safety and livability through lighting, greenery, and coherent public spaces can foster resilient, socially connected communities amid urban transformation.

Limitations and Future Research

The cross-sectional design captures connectedness at one point in time and cannot trace how attachment evolves with ongoing transformation. The focus on neighborhoods near a single industrial estate in Thailand may limit generalizability, and the street-intercept sampling may underrepresent less-mobile residents. While socio-demographic differences between old and new neighborhoods were observed, their moderating effects were not directly tested.

Future research should adopt longitudinal designs to trace how physical–spatial change influences attachment over time, extend testing of the model in varied cultural and urban contexts, and integrate spatial analyses such as GIS to complement perceptual measures. Mixed-method approaches combining surveys with qualitative insights could deepen understanding of how residents interpret physical–spatial

conditions in their everyday lives. Such efforts will further refine the theory and practice of neighborhood connectedness, ensuring that urban design and planning interventions remain responsive to both universal needs and local realities.

CONCLUSION

This study set out to examine how physical-spatial dimensions influence neighborhood connectedness in the context of urban transformation and whether these dimensions operate consistently across old and new neighborhoods shaped by industrial development. Grounded in place attachment theory and urban form perspectives, the research developed and validated a multidimensional model of neighborhood connectedness comprising six dimensions: Proximal Facilities, Pedestrian Friendliness, Vibrancy, Pleasantness, Road Network, and Crime and Safety.

The findings contribute to theory in two important ways. First, they extend the conceptualization of place attachment by demonstrating that physical-spatial features are not secondary backdrops but integral determinants of connectedness. Second, they advance urban form theory by showing that the salience of specific spatial attributes, such as pedestrian infrastructure, is context-dependent: universally relevant yet locally contingent. The partial invariance of Pedestrian Friendliness highlights how settlement history, density, and social networks shape the relative weight of physical affordances in fostering attachment.

The novelty of this study lies in its transferable measurement model, validated through second-order confirmatory factor analysis and invariance testing. This approach offers scholars and practitioners a robust framework for analyzing neighborhood connectedness in diverse urban contexts, particularly those experiencing rapid transformation. Beyond academic contributions, the study provides actionable insights for urban planners and policymakers. Ensuring access to proximal facilities and supporting vibrant land-use mixes should be central strategies for building connected neighborhoods. In new, high-density areas, investment in pedestrian safety and

connectivity is critical, while in older neighborhoods with stronger social capital, enhancing shared communal spaces and integrating multimodal mobility may be more effective.

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