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Research Article

Street Network Configuration and Vacancy in Inner-City Informal Settlements: A Space Syntax Analysis of Surabaya's Kampungs

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Abstract: Inner-city settlements are not free of risks such as vacancy and abandonment despite their importance in providing housing for citizens and migrant workers. This paper explores the vacancy issue in informal inner-city settlements and examines it through the street network configuration using syntactic measures such as connectivity, integration, and choice. This research studied 16 kampungs in the inner-city area of Surabaya, which were selected based on a set of criteria. Field observations were conducted to collect vacancy data alongside the Space Syntax Analysis, using DepthmapX to analyze angular connectivity, Normalized Angular Integration (NAIN), and Normalized Angular Choice (NACH) at global and local distances. A regression analysis with SPSS was also conducted to understand the significance of each value to the existence of vacant properties. The result shows that a vacancy is more likely to occur where the street has a lower value of angular connectivity but a higher value of NAIN and NACH, both in global and local distance. However, only angular connectivity and NAIN in the global radius are significant in this occurrence. These findings have practical implications for urban planners, policymakers, and community organizations, highlighting that excessive permeability threatens residents' sense of privacy and safety while accessibility is vital for sustaining the link between kampungs and the broader city.

Keywords: Inner-city; Kampung; Space syntax analysis; Street network; Vacant properties

1. Introduction

The inner city is a city's spatial, political, and cultural center, marked by high density, mixed functions, and concentrated services (Pesch, 2018). These areas are also the oldest and most vulnerable to deterioration in many Asian cities. Singh, 2015 noted that such a decline often attracts low-income renters. Commercial facility growth further influences vacancy or abandonment (Buitelaar et al., 2021). Much of the existing research links these changes to property sales in kampungs near main streets or malls. Setijanti et al., 2018 found that houses in Kampung Kaliasin, Surabaya, were being offered to developers, while in Cikini, Jakarta, higher-income buyers converted kampung houses into offices, a process accelerated by rising property taxes (Mardhotillah and Gamal, 2018). Recent studies also suggest that physical underuse and abandonment in inner-city areas are often embedded within broader spatial–social deprivation patterns, in which accessibility, exposure, and socioeconomic stress interact rather than operate independently (van Nes and López, 2013).

Recent discussions on sustainable urban development emphasize the need to reconsider the built environment as an interconnected system in which spatial configuration plays a critical role in shaping environmental performance, social conditions, and long-term urban resilience (Whulanza et al., 2025). This study examines the relationship between vacancy and street-network configuration, focusing on syntactic variables such as connectivity, integration, and

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choice. Although kampungs have been widely studied, the spatial mechanisms underlying vacancy, especially in relation to street morphology, have received limited attention in Surabaya and Indonesia. Using these syntactic measures allows us to observe the spatial distribution of vacant properties and understand why some kampungs become more vacant than others, even when they are located in highly accessible areas.

1.1 Inner-city area problems in developing countries

Inner cities in many developing countries remain desirable for their proximity to employment (Silas, 2017). However, they also experience cycles of decline. In South Africa, inner-city dereliction intensified after apartheid as businesses and wealthier residents moved outward, leaving behind "bad buildings" or "dark buildings" lacking basic services (Wilhelm-Solomon, 2020). In São Paulo, despite the strong infrastructure, central areas still have extensive vacancies. Nadalin and Igliori, 2017 found that districts closer to the city center have fewer derelict buildings, whereas peripheral zones experience higher vacancy rates.

In Indonesia, Jakarta's kampungs, often in strategic inner-city locations, are seen as obstacles to modernization (World Habitat Awards, 2024), and redevelopment pressures encourage the conversion of informal land into high-rise housing (Suhartini and Jones, 2023). At the same time, rising demand for centrally located affordable housing has intensified overcrowding and slum formation, as seen in Bandung, where inadequate services and fragmented land contribute to deteriorating kampung conditions (Jones, 2017). These examples illustrate two recurring outcomes of inner-city transformation: (1) dense occupation of informal settlements due to proximity to urban services and (2) displacement or premature vacancy caused by redevelopment pressures and fear of eviction.

1.2 Inner-city settlements of Surabaya

By 2045, an estimated 70% of Indonesians (220 million people) will live in cities (Roberts et al., 2009). As a major metropolitan core, Surabaya continues to attract workers and requires affordable housing. Kampungs have long fulfilled this role. Some kampungs predate colonial occupation and formed proto-urban settlements, while others emerged as indigenous residential areas during the colonial period (Krausse, 1975). Ford, 1993 noted that inner-city kampungs, positioned between old and new urban cores, were dense but increasingly pressured by commercial intrusion. Their strategic location has long drawn migrant workers seeking employment.

In Surabaya, a kampung is part of a neighborhood. It can be located anywhere in the city center, inner city, or fringe area. In the 1990s, 63% of Surabaya's inhabitants lived in kampungs, although these informal settlements only covered 7% of the city's area (Silas, 1992; Silas, 1989). The 2022 data (Surabaya Development Board (BAPPEKO), 2023) indicated that the kampung area covered 22.7% of the city, compared with the formal housing area, which covered 15.8%. The rapid development of formal housing and real estate in the east and west of Surabaya continues to increase the demand for formal housing. Simultaneously, the land shortage in the city center stagnated the kampung expansion.

Kampungs remain important for both citizens and migrants. The growing service and trade sectors continue to attract new residents (Nasution and Kurose, 2023). Their proximity to major activities and the rise of boarding houses linked to the mall boom (Peters, 2010) reinforces their significance. However, inner-city kampungs are increasingly at risk of vacancy. Large development projects around the CBD create uncertainty about their long-term future (Shirleyana et al., 2018), and declining populations in their subdistricts as shown in Table 1 (Statistics Bureau of Surabaya, 2022), show emerging pressures. The kampung locations within these subdistricts are shown in Attachment A.

1.3 Physical properties of a Kampung

A kampung is an urban vernacular settlement. (Geertz, 1965) described it as an urban form resembling village life but with a denser and more diverse form. During the Japanese occupation, kampungs were administrative units (RW) derived from the Japanese tonarigumi system (Funo, 2021). Today, RW remains the smallest governmental extension, facilitating administration and community coordination. In this study, kampungs are defined by RW boundaries due to the lack of formal delineation.

Table 1 Population in the subdistricts where inner-city kampungs are located

Subdistrict	Population		Growth
	2017	2021	
Tegalsari	107,070	98,288	-8.20%
Genteng	62,028	58,114	-6.31%
Bubutan	106,721	97,573	-8.57%
Simokerto	102,654	93,793	-8.63%
Pabean Cantikan	85,069	74,820	-12.05%
Semampir	199,578	183,344	-8.13%
Krembangan	123,750	114,618	-7.38%
Kenjeran	167,031	174,180	4.28%
Tambaksari	233,502	225,180	-3.56%
Gubeng	142,527	134,467	-5.66%
Sawahan	214,252	200,341	-6.49%

Kampungs are characterized by social relations and collective activities, as well as distinct physical features (Table 2). They are typically concealed behind commercial buildings and accessible through gates or narrow entry alleys. Inside, irregular networks, narrow alleys, and small junctions that often become informal social spaces are found (see Attachment B). Buildings include detached houses, boarding houses, small shops, and public facilities such as halls and mosques. These physical forms are strongly linked to social patterns. Padawangi et al., 2022 highlighted the continuing importance of religious institutions as centers of care, while Damayanti and Kossak, 2016 showed that kampung spaces can be perceived differently across gender groups.

1.4 Application of Space Syntax in Inner-City Studies

Space syntax has been widely used to examine the relationship between movement and urban morphology. Earlier studies have more broadly focused on inner cities, historic quarters, and urban transformation. Can and Heath, 2016 compared street patterns and activities across different neighborhoods in Izmir. Thinnakorn et al., 2023 used Space Syntax to analyze the preservation of centrality in the old town of Sakon Nakhon. Miranda et al., 2020 applied it diachronically to assess Évora's urban centralities, while Yin et al., 2021 used similar methods to compare spatial structures in the capitals of Tang and Song.

Space Syntax has also been applied to specific phenomena, such as crime distribution in Pisa (Mara et al., 2022) or accessibility changes in Erzurum's historic routes (Has, 2022). Although vacancy has occasionally been included as a variable in city planning for Jeddah (Acharya et al., 2017) or residential complexes in Tirana (Yunitsyna and Shtepani, 2023), dedicated analyses of vacancy within inner-city kampungs remain rare. More recent applications of space syntax have extended its use beyond movement prediction, demonstrating its capacity to reveal spatial exposure, safety concerns, and vulnerability in everyday urban environments (Istiani et al., 2023).

Table 2 Physical properties used to identify a kampung

Properties	Reference(s)
Context	
- Enclosed, hidden from the public gaze of the formal city	Nugroho and Zhang, 2022, Dovey and King, 2011
- Close to job opportunities, off the street, behind commercial facilities	Shirleyana et al., 2018
- Large shops/commercial facilities on the main road	Putra and Indrajati, 2021
Kampung circulation	
- Narrow alleyways	Putra and Indrajati, 2021 and Shirleyana et al., 2018
- Irregular network pattern, organic street form	Perkasa et al., 2022 and Dovey and King, 2011
- Equipped with entryway	Shirleyana et al., 2018, Putra and Indrajati, 2021
- No vehicle access	Perkasa et al., 2022, Shirleyana et al., 2018, Dovey and King, 2011
Public/social space	
- Appropriation of alleyways	Putra and Indrajati, 2021, Mappajaya et al., 2019, Damayanti and Kossak, 2016
- Designated public space	Putra and Indrajati, 2021, Mappajaya et al., 2019, Damayanti and Kossak, 2016
Building-related features	
- Religious building as a coordination center	Padawangi et al., 2022
- A mix of housing types	Perkasa et al., 2022, Shirleyana et al., 2018, Peters, 2010
- Vacant houses	Shirleyana et al., 2018
- Small shops / food vendors inside the kampung	Putra and Indrajati, 2021, Shirleyana et al., 2018, Damayanti and Kossak, 2016

2. Methods

The study began by determining the research location and preparing field and spatial datasets. An aerial map was used to identify vacancies during fieldwork, while a road center line (RCL) map was prepared for Space Syntax analysis using DepthmapX. The steps outlined by Kolovou et al., 2017 were followed to prepare the RCL map, which was then converted into a segment map. Connectivity, choice, and integration values were averaged to compare streets with and without vacant properties. A regression analysis using the Statistical Package for the Social Sciences was conducted to determine the significance of each syntactic measure. Figure 1 presents the research framework.

Based on the research framework in Figure 1, the input stage comprises spatial data (aerial and road-centerline maps), field-mapped vacancy information, and historical references used to identify and delineate inner-city kampungs. The process stage includes map preparation and the conversion of the road center line into a segment map, followed by Space Syntax analysis (angular connectivity, NAIN, and NACH at global and local radii) and quantitative analysis using descriptive statistics and regression in SPSS. The output stage produces spatial layers

(vacancy and syntactic maps), analytical findings identifying significant vacancy predictors, and interpretive insights on the spatial and socio-spatial dynamics influencing vacancy in Surabaya's inner-city kampungs.

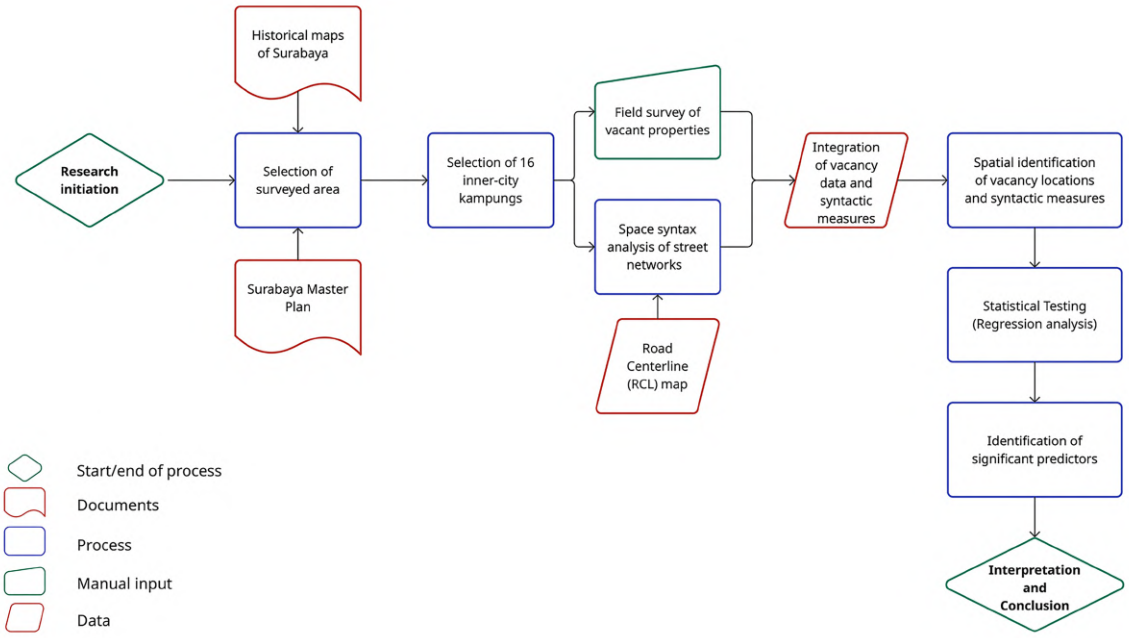

Figure 1 Research framework diagram showing input-process-output

2.1 Area Selection

The inner-city kampungs were delineated based on the RW boundaries and their historical presence before or during the colonial occupation. The base map was taken from the 2014-2034 master plan of Surabaya (see supplementary file) to define commercial/business areas. An 1880 map from the Topographisch Bureau van de Generale Staf Batavia was used to find areas registered as kampungs and the main roads during this period Statistics Bureau of Surabaya, 2022. Based on this map, kampungs were located around the main circulation area of the city. Additional areas were recognized as kampungs on the map of 1925 (Van-Ingen, 1925). Sixteen kampungs, all located in or near the city center, were selected for analysis to allow spatial comparison in similar urban contexts.

2.2 Field Survey

Fieldwork was conducted from November 2022 to November 2023. Official occupancy data were unavailable; thus, vacancy information was collected manually, along with building use, social spaces, and other kampung features. Only vacancies inside kampungs (not their surrounding shells) were included in the analysis.

2.3 Use of Space Syntax Analysis

Space syntax describes how spaces are arranged in relation to how people perceive, move through, and use spatial systems at any scale, from the domestic to the urban (Karimi, 2012). Angular segment analysis (ASA) was chosen for the space syntax analysis. The angular segment analysis is related to the cognitive behavior of a person who is likely to choose the least angular path when moving from one point to another (Kolovou et al., 2017). This analytical assumption follows recent space-syntax-based studies that interpret configurational measures as indicators of environmental stress, safety, and usability, rather than movement alone (Istiani et al., 2023).

According to Hillier and Iida, 2005, despite attempts to minimize distance, people's concept of distance is shaped more by the network's geometric and topological properties than by their ability to measure the metric distance. Thus, people comprehend the urban network in geometrical (least-angle) and topological (least-turn) terms rather than metric terms.

The road centerline (RCL) map was used for the space syntax analysis. RCL can improve space syntactic measures by leveraging a combined road-centerline model analyzed using angular-weighted betweenness within a metric radius (Turner, 2007). This map is transformed into a segment map and used to analyze syntactic measures, including connectivity, integration, and choice. Integration represents the to-movement potential of a space, and choice represents the through-movement potential. The two measures correspond to the two basic elements of any trip: selecting a destination from an origin (integration) and choosing a route between the origin and destination (choice) (Hillier et al., 2012).

This study examined 16 kampungs in Surabaya's inner city, which vary in layout and size. The normalization of integration and choice is necessary because the cases varied (Soltani et al., 2020). Normalizing the key measures of integration and choice for angular systems would enable the comparison of cases of different sizes and forms (Hillier et al., 2012). Thus, the normalized values using angular distance in this research were Normalized Angular Choice (NACH) and Normalized Angular Integration (NAIN). Integration and choice were analyzed in global and local radii. The global radius is essential for exploring possible movement behavior from the kampung to the city network. Kampung inhabitants typically use the citywide network to access their workplace or other facilities by motorcycle. Meanwhile, a 400-meter radius was used to observe movement within walking distance of the kampung.

3. Results and Discussion

Space syntax analysis of the kampung street networks was examined through angular connectivity, normalized angular choice, and normalized angular integration at both global and local radii and grouped according to whether a street segment contained vacant properties. As summarized in Table 3, a consistent pattern emerges across most of the sixteen kampungs: street segments with vacant properties tend to exhibit lower angular connectivity but higher integration and choice values. Kampungs with the highest vacancy rates, such as Alun-Alun Contong (26.29%), Tambak Bayan (19.60%), Blauran (16.17%), and Praban Wetan (13.71%), display this contrast most strongly. This indicates that locally underconnected alleys can still be highly exposed within the broader circulation network. Kampungs with relatively low vacancy rates, such as Genteng (4.14%), Kawatan–Bubutan (5.37%), and Lawang Seketeng (5.34%), show a weaker expression of this pattern, suggesting that either stronger internal connectivity or reduced external exposure may help sustain occupancy. From the perspective of urban well-being, such concentrations may signal environments that undermine perceived safety, comfort, and everyday livability, rather than merely reflecting inefficient land use (Whulanza and Kusrini, 2023).

However, a few kampungs behave differently. For instance, in Kawatan, Bubutan, Genteng, and Blauran, the NACH values for vacant segments do not consistently exceed those of non-vacant segments. These deviations highlight that while the overall trend is robust, local conditions, such as street typology, internal circulation roles, or adjacency to commercial edges, may soften or reverse the expected relationship between syntactic measures and vacancy. Nevertheless, when viewed collectively, the broader pattern remains clear: the spatial tension between limited local connectivity and greater global or local exposure significantly shapes vacancy across the kampungs. The following subsections elaborate on how each syntactic measure contributes to this pattern.

Table 3 Mean value of syntactic measures on sixteen kampungs' streets grouped by the existence of vacant properties

No.	Kampung	angCONN		NACH		NACH r400m		NAIN		Vacant
		V	NV	V	NV	V	NV	V	NV	%
1	Maspati	1.295	1.942	0.913	0.797	0.965	0.915	0.855	0.830	7.73
2	Kranggan	0.966	1.756	0.951	0.773	1.156	0.922	0.792	0.739	10.43
3	Kawatan	1.232	1.454	0.679	0.736	0.786	0.861	0.958	0.925	5.37
4	Bubutan	0.797	1.711	0.954	0.855	1.062	0.969	0.982	0.957	11.96
5	Praban Kulon	1.630	2.179	0.960	0.779	1.097	0.936	0.975	0.948	13.71
6	Alun-Alun Contong	1.676	1.713	0.727	0.711	0.869	0.811	0.932	0.794	26.29
7	Tambak Bayan	1.355	1.945	0.701	0.642	0.858	0.740	0.863	0.843	19.60
8	Jagalan	1.226	1.613	0.812	0.792	0.921	0.871	0.823	0.793	7.39
9	Lawang Seketeng	0.763	1.712	0.957	0.825	1.036	0.983	0.805	0.762	5.34
10	Pandaan	0.542	2.150	0.986	0.844	1.073	1.007	0.799	0.742	8.47
11	Peneleh	0.983	1.771	0.902	0.756	0.970	0.918	0.816	0.719	8.79
12	Plampitan	0.886	2.250	0.966	0.742	1.057	0.862	0.785	0.772	9.36
13	Genteng	0.562	1.242	0.815	0.830	0.992	0.955	0.769	0.757	4.14
14	Tunjungan	1.968	1.782	0.933	0.779	1.016	0.873	0.783	0.726	8.47
15	Blauran	2.898	2.012	0.877	0.911	0.979	0.991	0.973	0.960	16.17
16	Plemahan	1.398	1.522	0.993	0.900	1.082	1.007	0.754	0.714	7.08

Note: V = section of streets with vacant properties;
NV = section of streets without vacant properties

3.1 Angular Connectivity

The angular connectivity values across the kampungs revealed that vacant properties were more likely to appear on segments with lower connectivity (Table 3). Kampungs with irregular, tree-like networks or dead ends, typical of informally developed fabric, exhibit heightened vacancy risk in alleys with limited directional choices (Figure 2). A street that lacks branching alleys or forces long, uninterrupted walking distances provides fewer opportunities for daily encounters, reducing the micro-scale social presence that usually sustains occupancy in kampungs.

This finding aligns with the idea that connectivity reflects the local movement potential of a space. Higher connectivity typically boosts vitality in commercial settings, but the relationship is more delicate in residential kampungs. When connectivity is low, everyday interaction and natural surveillance diminish, making certain locations less desirable to inhabit. This dynamic helps explain why dead-end alleys and poorly connected segments repeatedly emerge as vacancy hotspots, even though residents rely heavily on local circulation to access daily necessities.

However, exceptions, such as Kampung Tunjungan (no. 16 on the map), indicate that connectivity cannot be interpreted in isolation. In some cases, alleys with high external exposure may appear well-connected but still struggle with occupancy due to broader urban pressures, as elaborated in later subsections.

3.2 Normalized angular integration

Vacancies also tend to cluster on alleys with higher global integration. Globally integrated segments provide more direct access to the citywide network (Figure 3), potentially exposing unfamiliar individuals to unwanted exposure. In kampungs, where houses often open directly onto narrow alleys without fences, even small increases in through-movement affect privacy and comfort.

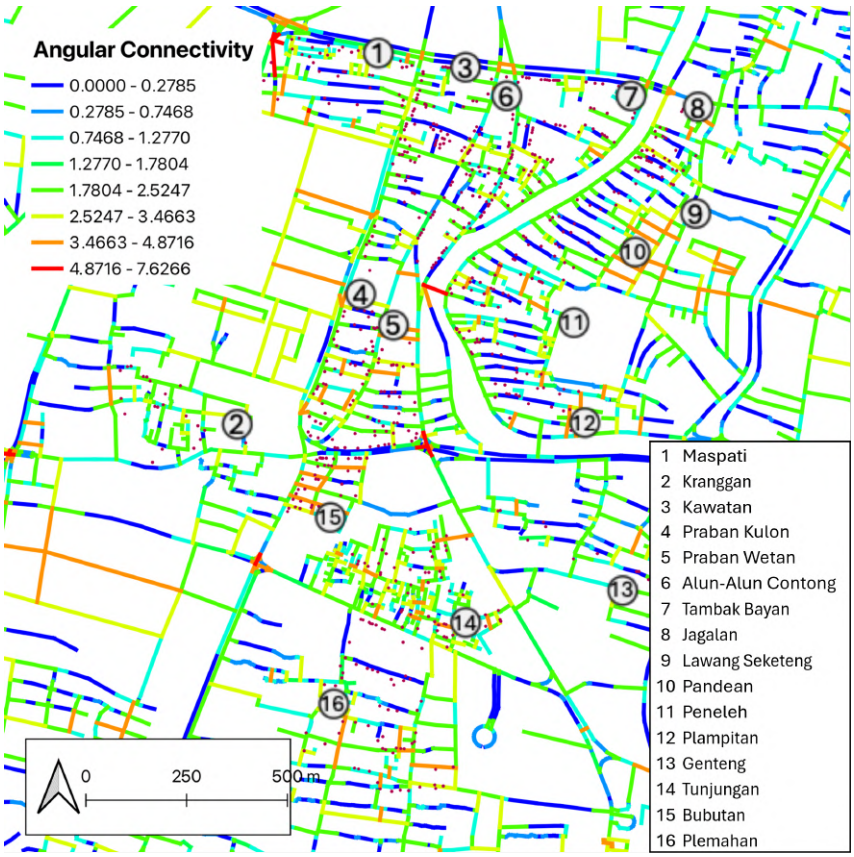

Figure 2 Angular connectivity of street segments across 16 kampungs in Surabaya's inner city

This locally isolated but globally exposed tension emerges as a recurring spatial condition associated with vacancy. Streets with low connectivity yet high global integration are accessible to outsiders but lack strong internal circulation. This combination heightens the sense of vulnerability: it limits familiar foot traffic but increases visibility to transient flows.

On the other hand, NAIN within a local radius shows how the street networks are connected within a walkable radius of 400 m, indicating the distance to move within or around the kampung. Locally integrated alleys (within 400 m) are straighter, involve fewer turns, and often connect to wider entry points. These segments also have a higher vacancy rate (Figure 4). In Kampung Peneleh (no. 11 on the map), the outer section of the alley with a higher local NAIN contains more vacant properties, whereas the inner section contains fewer (Figure 5). Despite being in the same alley, local integration differences closely correspond to occupancy.

This pattern reinforces that integration, while essential for movement, becomes problematic when excessive pedestrian or vehicular flow compromises the sense of privacy. The kampung's morphological logic —narrow alleys, close building frontage, and direct doorway exposure—amplifies the consequences of increased visibility.

Figure 5 compares two alleys in Kampung Peneleh (no. 11) with different local integration values. Both images depict the segments of Peneleh 3. The left section (a), which connects directly to the main street on the west and another alley on the east, has a higher local integration value and contains five vacant properties. The right section (b), with lower integration, contains fewer vacancies and appears to be more maintained, with greener frontage and quieter circulation. Connectivity, integration, and choice in space syntax indicate how accessible a space is within a network. In commercial contexts, higher accessibility is beneficial: van Nes and Yamu, 2021 showed that angular choice correlates with shop distribution in Lyu et al., 2023 found that accessible areas often become gathering spaces. However, this relationship becomes more complex in dense inner-city kampungs. Table 3 shows that vacancies are more likely in areas with low connectivity.

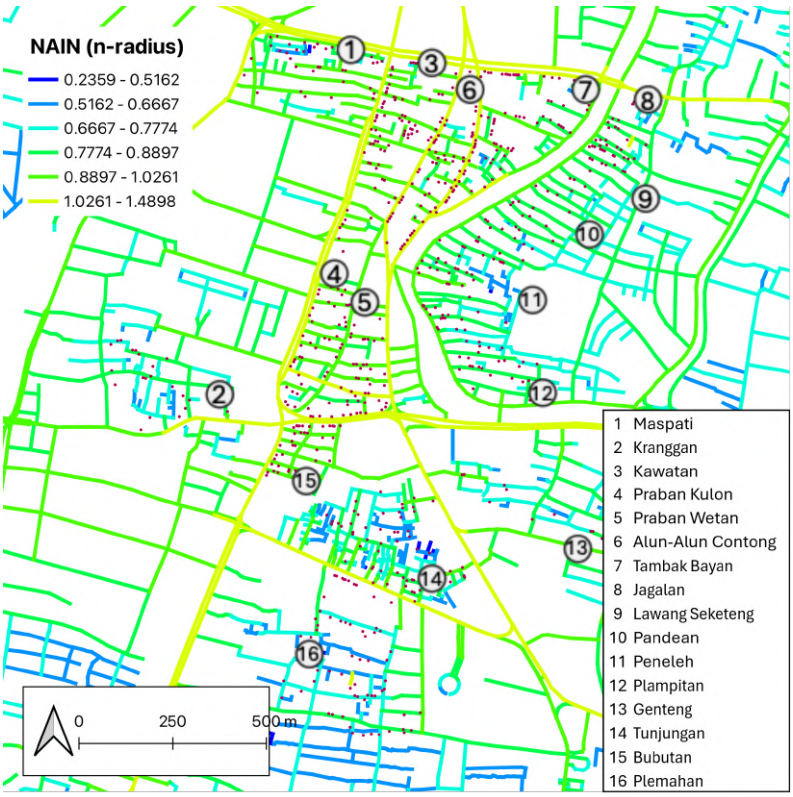

Figure 3 Normalized angular integration (NAIN) in n-radius of street segments across 16 kampungs in Surabaya's inner city

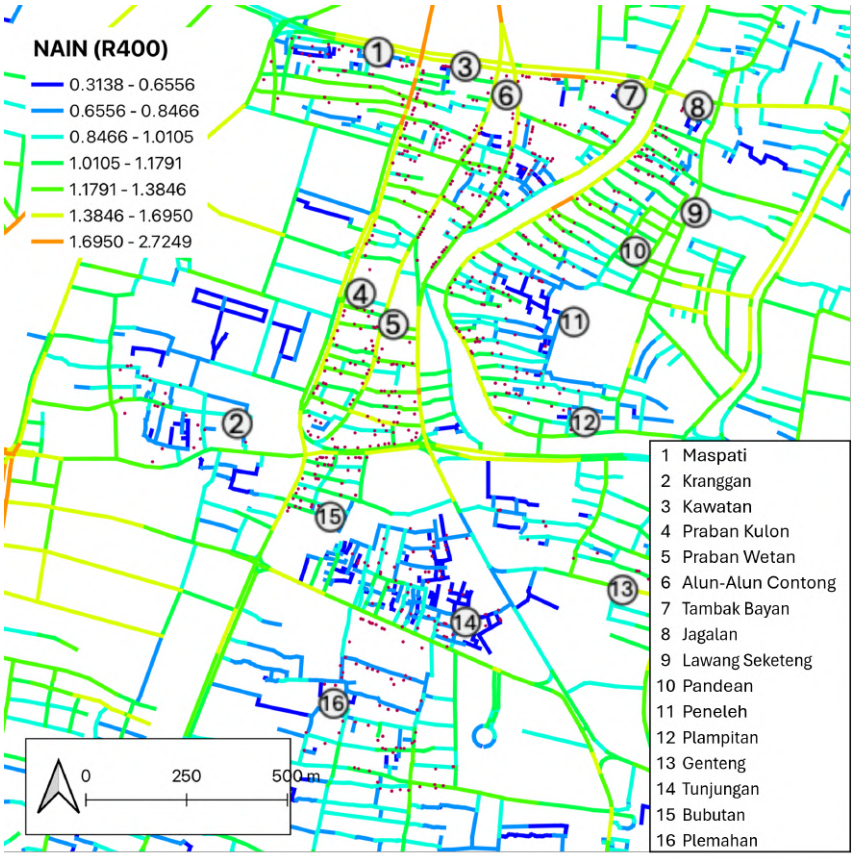

Figure 4 Normalized angular integration (NAIN) R400

However, integration and choice are high, showing that kampungs that are highly integrated into the wider urban network but weakly connected internally are more vulnerable to vacancy. This mismatch between local isolation and broader exposure increases transient movement visibility while reducing everyday familiarity.

Such exposure may also heighten vulnerability to petty crime. Kampungs with higher NAIN and NACH values, including Tunjungan (no. 14), Jagalan (no. 8), Peneleh (no. 11), and Plemahan (no. 12), have recorded theft, mugging, or narcotics cases in recent years. Reported incidents include thievery (Syaifuddin, 2022) and narcotics distribution in Tunjungan (Syaifuddin, 2023a); mugging and repeated narcotics activity in Jagalan (Mahrus, 2024; Wijayanto and Irianto, 2023; Syaifuddin, 2023b;); multiple muggings in Peneleh (Setiawan, 2021; Supriyadi, 2020); and theft or narcotics-related incidents in Plemahan (Setiawan, 2022; Manna, 2020). These patterns support Hillier and Sahbaz, 2008 argument that excessive or poorly moderated permeability can elevate crime vulnerability and echo Sampson and Groves, 1989 observation that weakened neighborhood ties reduce informal social control.

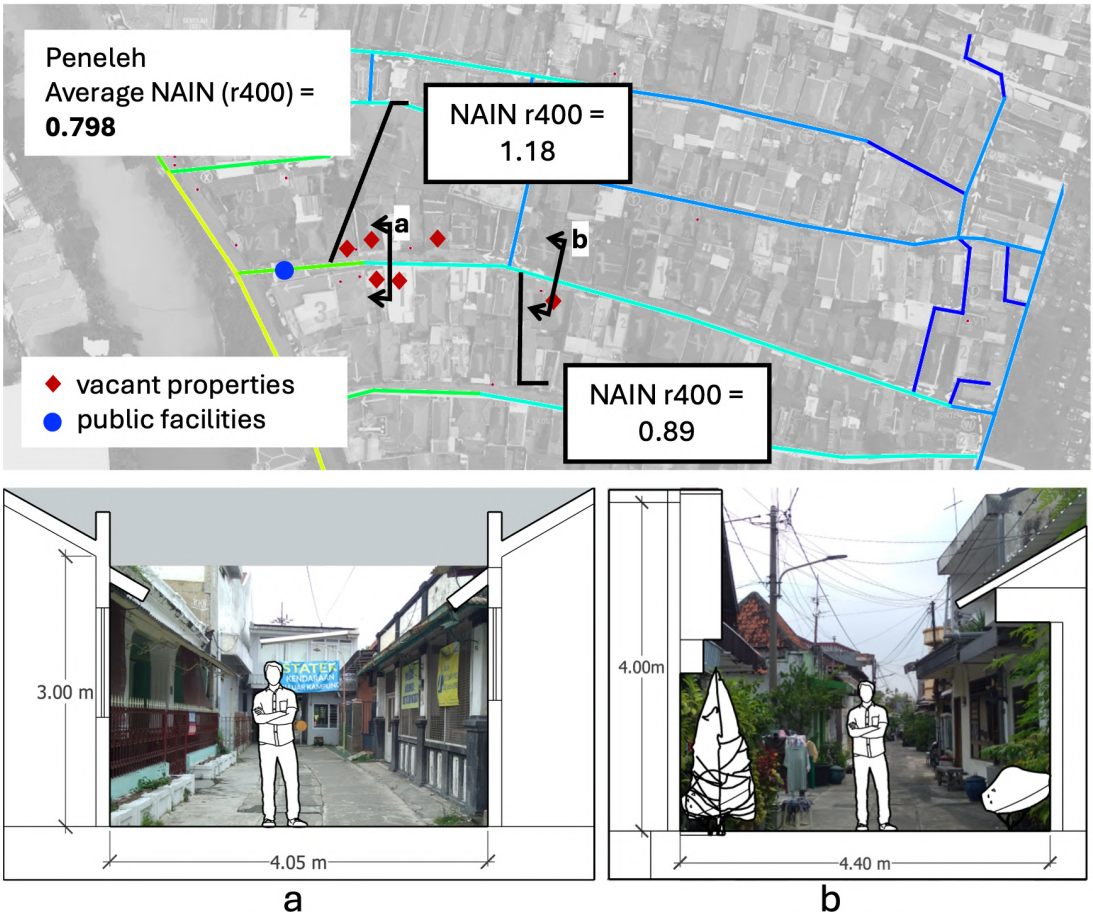

Figure 5 Alley in Kampung Peneleh (no. 11) with varied NAIN R400 values

Interviews reveal that many residents still perceive their kampungs as "quite safe," relying on familiarity, neighbor recognition, and intermittent collective vigilance (Interviewees T, N, and U, personal communication, January 2023). This contrast between perceived safety and actual incidents indicates that vulnerability arises not simply from crime but also from the interaction between spatial exposure and fluctuating community oversight.

3.3 Normalized angular choice

Global NACH highlights segments that are most likely to be selected as through-routes within the larger city network. Streets with higher global choice values are more likely to be vacant (Table 3). Although internal to kampungs, these segments inadvertently function as

shortcuts or connectors for people traversing the urban grid (Figure 6a). Their unintended role as movement corridors increases anonymity and reduces alley users' predictability.

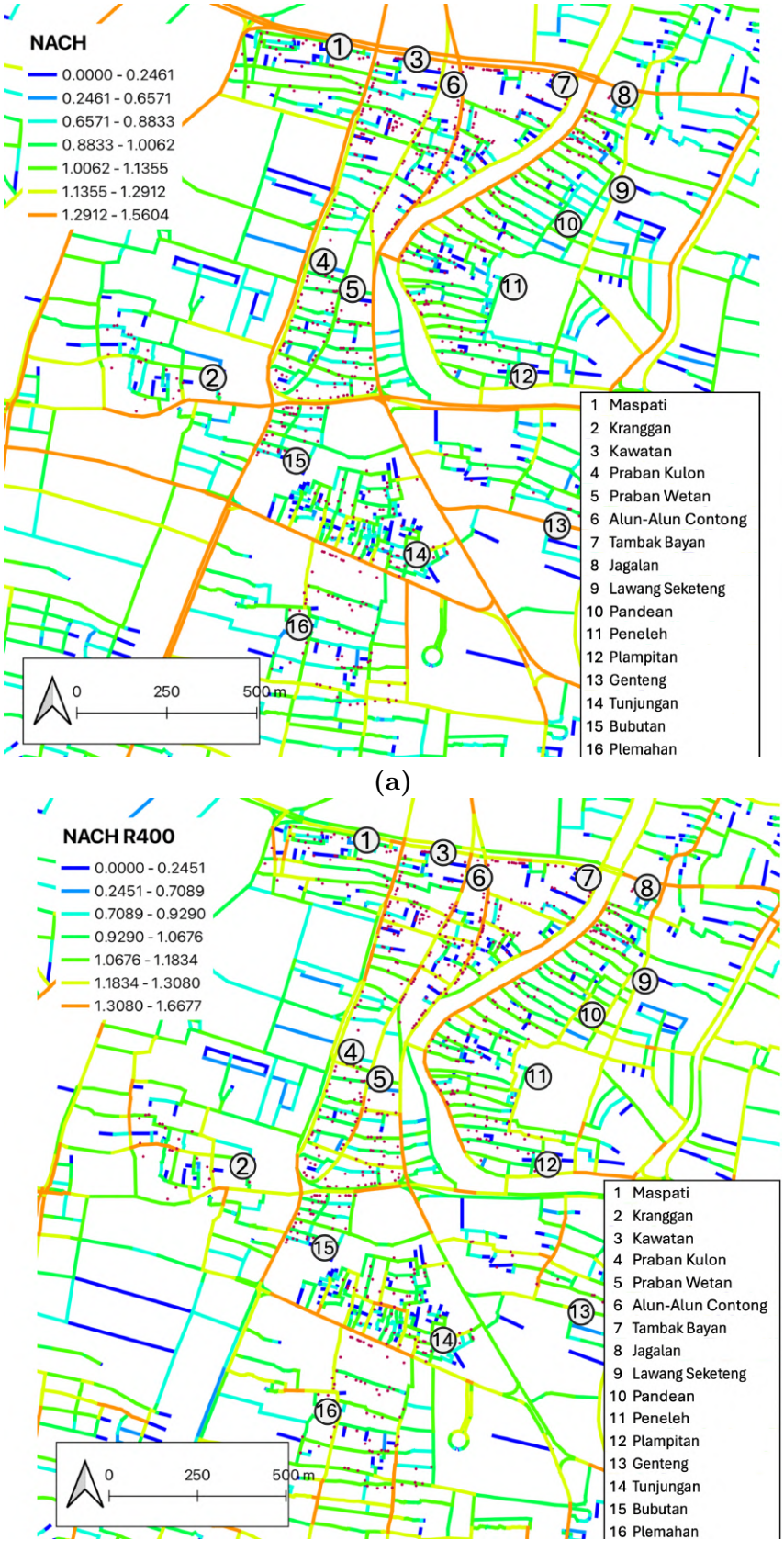

Figure 6 Normalized angular choice (NACH) (a) n-radius and (b) 400-m (R400) radius

Local NACH (within a 400 m radius), as shown in Figure 6b, identifies alleys that shape

the internal circulation. Kampungs such as Tambak Bayan (no. 7) and Tunjungan (no. 14) tend to accumulate vacant properties because they serve as main internal connectors, market extensions, or access points to major streets (Figures 7 and 8). High local choice means more footfall and circulation, which is beneficial for commerce but less so for housing whose doors and windows open directly to the alley. The presence of vacancy along high-choice alleys mirrors global NAIN findings: uncomfortable levels of visibility, increased risk of intrusion, and reduced privacy may discourage long-term habitation.

The Kampung Tambak Bayan section shown in Figure 7 illustrates a situation with different NACH ranges in one location. Alley (c) has a higher NACH value than its surroundings inside the kampung. The street is wide and well-connected to the main street; therefore, it has been used as an extension of the local market. Ironically, vacant houses began to appear along the alley as a result of this utilization. On the south side, alley (d) has a lower NACH value. However, because alley (d) connects two other alleys, it remains significant in facilitating circulation to the main street. Alley (e) is a junction to a dead end and other smaller alleys, which lessened its significance as a circulatory route to and from the main street.

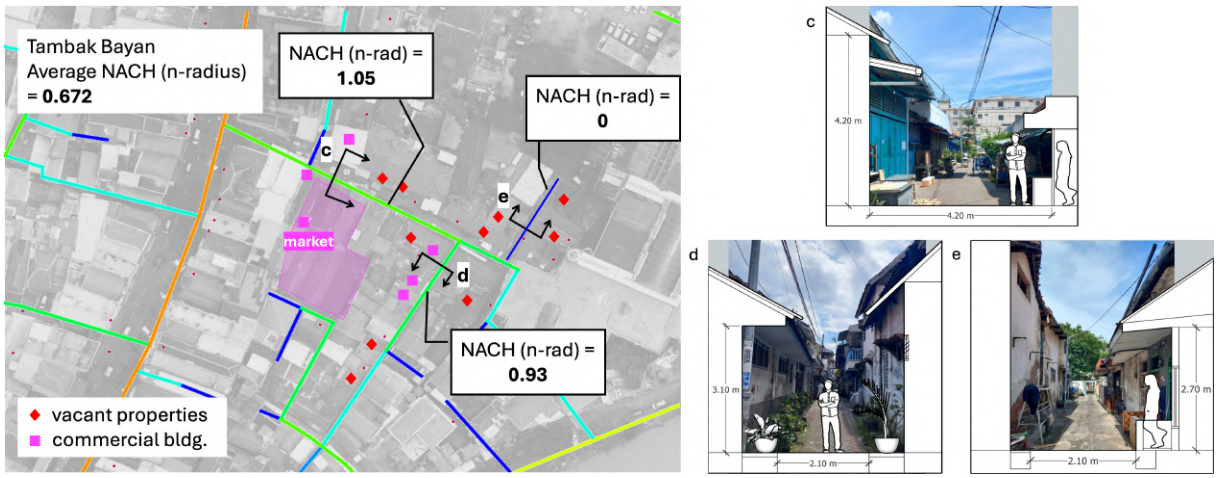

Figure 7 A section of Kampung Tambak Bayan (no. 7) with varying NACH n-radius values

Another example of NACH within the local radius can be seen in a section of Kampung Tunjungan (Figure 8). In this section, the alley with the thicker line indicates a higher level of local choice, indicating that it became an essential passage for circulation at some point. Alley (f) has some intersections connecting the inner part of the kampung to the main street to the south, making its choice value higher than that of other alleys. It also serves as an on-street public space for occupants. The adjacent alley (g) is connected at its ends to other alleys. The conditions between these two alleys are distinct. While it is the main route, Alley (f) is noticeably narrower, thus leaving less room for improvement on its street compared to Alley (g). Its size also limits the types of activities it can contain. Alley (g) has a broader range of activities, including on-street parking, laundry drying, and play space.

3.4 Significance of Syntactic Measures

The regression results in Table 4 indicate that angular connectivity and global NAIN are the only statistically significant predictors of vacancy ($p < 0.05$). Connectivity shows a negative relationship, meaning that vacancy increases as connectivity decreases. Meanwhile, global integration shows a positive relationship, meaning that vacancies rise as integration grows. The model explains 41.2% of the vacancy variance.

The remaining variance likely stems from non-spatial but spatially linked factors. Some kampungs with lower syntactic values do not exhibit high vacancy because social cohesion and internal micro-economies counteract spatial disadvantages. Boarding houses, self-managed public spaces, street vendors, mosques, and community halls create a continuous social presence,

stabilizing occupancy even where spatial conditions may otherwise encourage vacancy.

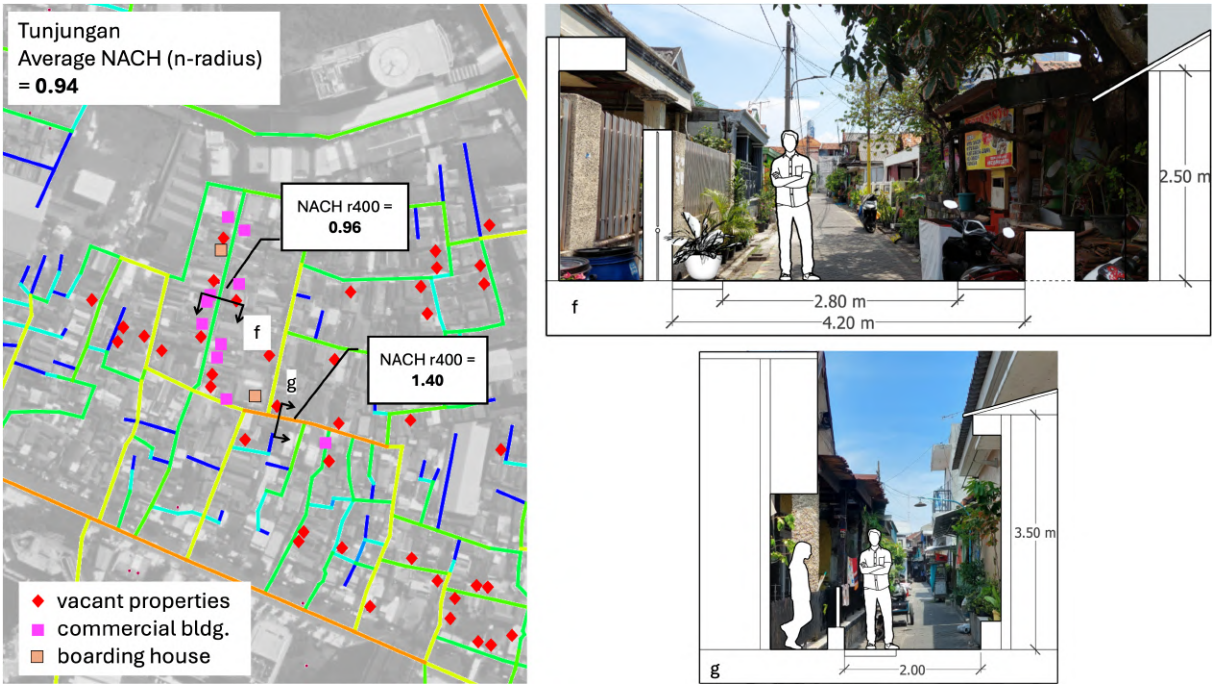

Figure 8 A section of Kampung Tunjungan (no. 14) with varying NACH R400 values

Table 4 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R-square change	F Change	df1	df2	Sig. F Change
1	.642[a]	**.412**	.299	.722835	.412	3.639	5	26	**.013**

a. Predictors: (Constant), Normalized Integration R400, Angular Connectivity, Normalized Choice, Normalized Integration, Normalized Choice R400

Examples include Blauran (no. 15) and Kranggan (no. 2), in which, despite low connectivity or modest integration, communal infrastructure and everyday economic activity remain vibrant. In such cases, the internal social architecture of the kampung compensates for situations in which the spatial configuration alone would predict vulnerability. These findings show that vacancy in kampungs is not a syntactic phenomenon but a socio-spatial one: shaped by the interplay between street configuration, community interaction, local facilities, and broader urban pressures. These findings indicate that spatial configuration constitutes a form of urban intelligence, which complements policy-driven or technology-oriented approaches to sustainable urban development (Sutriadi et al., 2025).

Table 5 Coefficients of Regression Analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-4.147	2.151		-1.928	.065		
Angular Connectivity	-.735	.279	-.451	-2.634	**.014**	.771	1.298
Normalized Choice	-.370	3.832	-.042	-.097	.924	.118	8.461
Normalized Choice R400 value	3.224	4.138	.356	.779	.443	.108	9.236
Normalized Integration	5.623	2.535	.567	2.218	**.035**	.347	2.885
Normalized Integration (R400)	-1.466	1.693	-.229	-.866	.395	.322	3.104

a. Dependent variable: Number of vacant properties

4. Conclusions

This study highlights the importance of syntactic variables—connectivity, integration, and choice—in shaping vacancy patterns within inner-city kampungs in Surabaya. Connectivity reflects the ease of movement and local circulation, while integration and choice indicate the degree to which kampung streets are embedded within broader urban movement networks. The findings show that vacancy is more likely to occur where angular connectivity is low and global integration is high, showing that locally disconnected but globally exposed kampungs face a greater risk of abandonment. Higher local and global integration, as well as choice values, also correspond to vacancy presence, indicating that increased permeability in narrow, frontage-facing alleys may reduce residents' privacy, comfort, and sense of security. Despite these spatial tendencies, kampungs continue to demonstrate resilience. Field observations reveal that features such as boarding houses, small shops, self-managed public spaces, and communal facilities help maintain activity, interaction, and informal surveillance. These elements support local economies and strengthen social cohesion, thereby helping offset spatial disadvantages and reducing the likelihood of vacancy even in challenging spatial configurations. Nonetheless, commercial pressures, redevelopment plans, and crime incidents in more permeable alleys indicate that spatial exposure interacts with wider urban and social processes that shape the long-term stability of kampung environments. This study has not examined the three-dimensional aspects of kampungs, such as building heights, density variations, or vertical circulation, which could influence accessibility, visibility, and patterns of use. However, the two-dimensional analysis presented here offers insight into how street networks condition occupancy and vacancy. Future research could extend this work by integrating 3D spatial techniques, such as isovist mapping, visibility graph analysis, or measures of vertical integration, to more effectively capture the interaction between built form, spatial depth, and survivability in inner-city kampungs. The integration of cultural aspects, such as shared routines, collective practices, and norms of spatial appropriation, as well as time-bound dimensions that trace how vacancy and occupation fluctuate across daily, seasonal, and historical cycles are equally important. Considering these cultural and temporal layers alongside spatial metrics would allow a more comprehensive understanding of how kampungs persist and evolve within the pressures of the inner city. Additionally, property ownership patterns must be better understood, as they likely affect long-term stability and residents' ability to adapt to change. We can develop a more comprehensive understanding of how informal settlements, particularly those in high-pressure urban centers, sustain themselves over time by linking spatial qualities, physical infrastructure, and ownership structures. This research contributes to spatial theory by illustrating how street network configuration influences social and physical dynamics in informal settlements. This study highlights the importance of reading syntactic data alongside lived experiences and local conditions, especially in understudied urban contexts, such as kampungs. The findings indicate that protecting the internal connectivity of kampungs without overexposing them to external flows is critical for planners and policymakers. Locally driven improvements, such as maintaining shared spaces, securing property rights, and enabling small-scale commerce, can help reduce vacancy and strengthen social resilience. Rather than viewing kampungs as obstacles to urban development, they should be viewed as adaptable neighborhoods with embedded systems of care and sustainability

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Author Contributions

All authors conceptualized the paper, discussed the results, and contributed to the final manuscript. Tanti S.R. Nasution performed the Space Syntax simulation, analyzed the data in SPSS, and wrote the manuscript. Kurose verified the analytical method, reviewed and edited the

manuscript, and supervised the research. Participating Collaborators: Adinda S.P.R. Utami and Zuhrotul M. Ula (Field Survey managers); Mirra K. Ismail, Desmas A. Patriawan, Muhammad Ali, Ni Luh Tantri Pratisthita, Mutia Sulistiastuti (Field surveyors)

Conflict of Interest

The authors declare no conflicts of interest.

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