Identification and Analysis of Influencing Factors of Urban Informal Settlements Based on Multinomial Logistic Regression

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Abstract: Against the backdrop of rapid urbanization in Global South metropolises, the coexistence of formal and informal settlements constitutes a distinct spatial characteristic. A profound understanding of the spatial factors influencing their formation is crucial for advancing urban planning. By integrating multi-source remote sensing data, this study constructs a detection framework for socio-spatial differentiation in Global South cities, incorporating diverse indicators. Using Bangkok, Thailand, as a case study, it focuses on typical high-end settlements, informal settlements, and traditional settlements, aiming to quantitatively reveal the key spatial factors driving settlement differentiation. The study finds that building height, population density, and building density are core factors distinguishing different residential types, with building height being the most significant. This is attributed to residents in informal settlements being compelled to achieve extreme horizontal expansion of living space through densely arranged structures on limited land. This research validates the effectiveness of using explicit spatial indicators to reveal implicit socio-economic patterns. Its methodology and conclusions offer insights for promoting spatial justice in urban planning across the Global South.

1. Introduction

Since the 1960s, research initiated in Latin America on the economic lives of rural laborers in cities gradually developed the important concept of "urban informality." Early studies predominantly focused on labor and economic spheres, paying particular attention to two main types: the "informal economy" and "informal settlements." The emergence of "informal settlements" signifies a prevalent dichotomy between formality and informality in the urban environment: the former refers to spatial forms developed under the control of official planning systems; the latter constitutes incrementally produced, unauthorized, and self-organized urban communities.[1] Today, this informality is no longer confined to Latin America but has expanded into a ubiquitous urban phenomenon, manifesting in various forms such as slums, shantytowns, urban villages, street markets, and mobile vendors. They grow continuously outside formal institutions and planning controls in a bottom-up manner, collectively forming a complex and multi-layered map of urban informal space.

The widespread formation and continuous expansion of informal settlements also represent cities undergoing rapid yet highly uneven urbanization processes. This urbanization is more concentrated in the vast developing regions of Asia, Africa, and Latin America, namely the cities of the Global South.[2] According to UN-Habitat estimates, over one billion people globally live in informal settlements, the vast majority located in Global South countries. Based on current trends, this number could reach three billion by 2050. Thus, urban informality is no longer a marginal or transitional form but has become a norm, even a key mode of urbanization, in Global South cities.

Therefore, conducting research on informal settlements within the Global South framework holds particularly urgent practical and theoretical significance. These spaces, often perceived by mainstream narratives as symbols of disorder and chaos, actually nurture an inherent order beneath apparent chaos, and have developed unique characteristics in terms of spatial form, social structure, and economic function. They not only provide crucial shelter and diverse livelihoods for the urban low-income population but also contribute indispensable cheap labor and basic services to their cities, gradually exhibiting a certain systemic irreplaceability. As urbanization in the Global South continues to advance, systematic research on the characteristic identification and formation mechanisms of informal settlements from a spatial dimension will not only help understand their survival logic but also provide key evidence for more just and inclusive urban governance.

2. Literature Review

In recent years, research on informal settlements in the Global South has matured into a multidisciplinary academic field. Recent literature primarily revolves around three core dimensions: First, research on the formation mechanisms and internal dynamics of

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informal settlements, as seen in Ismail, Adu-Ampong et al.'s work on Abuja, Nigeria.[3] This dimension moves beyond viewing informality as a static entity, instead analyzing it as a continuously evolving socio-spatial process. Studies employ historical institutionalism frameworks to trace how critical junctures and path dependency shape governance dilemmas, and use morphogenesis to deconstruct their bottom-up, incremental urbanism and spatial self-organization patterns, exploring how they cope with vulnerability and claim rights through informal economies and community self-governance strategies. Second, research on governance and policy interventions for informal settlements, referencing Wang, Bazán et al.'s comparative study between Accra and Buenos Aires.[4] This dimension focuses on evaluating the effects and contradictions of different policy tools and explores possibilities for policy learning through cross-regional comparative studies. Third, research on climate vulnerability, health crises, and resilience building, based on Quesada-Román's disaster risk assessment. This emphasizes the vulnerability of informal settlements and their adaptation strategies in the face of external shocks like climate change and public health crises.[5]

Regarding the study of characteristics and causal analysis of informal settlements, existing research methods include using remote sensing and geospatial information technologies, utilizing high-resolution satellite and UAV imagery combined with machine learning algorithms for object-based image classification; or employing methods like the Analytical Hierarchy Process (AHP) and Principal Component Analysis (PCA) to determine weights and core variables, thus forming operational evaluation tools; additionally, field-based qualitative methods, such as ethnography, in-depth interviews, and participatory observation, can delve into the implicit dimensions inaccessible to technical means, such as informal land transaction rules, community governance structures, and residents' sense of place.

Methods like remote sensing and space syntax can accurately describe the spatial morphological characteristics of informal settlements but cannot scientifically prove whether these features are causes or effects.[6] More importantly, they cannot quantify the relative importance of multiple factors. Simultaneously, although multi-indicator evaluation systems like AHP attempt to synthesize multiple indicators, the determination of indicator weights often relies on expert scoring, introducing a degree of subjectivity. This study aims to transcend descriptive analysis, quantitatively reveal the core factors determining settlement types in the urban environment and their relative importance, thereby laying the foundation for a mechanistic understanding of informality and providing data-driven policy recommendations. It also necessitates the use of more universally available urban data so that the research results can be applied to broader Global South urban agglomerations.[7]

Therefore, to overcome the aforementioned limitations, this study will adopt a data-driven quantitative modeling approach, constructing a Multinomial Logistic Regression model with settlement type as the dependent variable and multiple easily accessible urban spatial elements as independent variables. This model will objectively select significant influencing factors from the data and precisely quantify the direction, strength, and relative importance of each factor's effect.

3. Methods and Data

This study proposes a detection framework for urban socio-spatial differentiation encompassing diverse indicators to reveal the characteristics of informal settlements in Global South cities for their identification. This framework consists of two steps: (1) feature extraction and (2) driver revelation.

3.1. Feature Extraction of Informal Settlements

For the extraction of spatial characteristic factors, the selected variables correspond to key dimensions within the five core deficiencies of informal settlements defined by UN-Habitat's World Cities Report 2020: The Value of Sustainable Urbanization. Among them, population density is a direct quantitative indicator of "overcrowding"; building density and average height jointly define the density and morphology of buildings in an area, useful for judging the degree of self-organized construction of housing; the Night-Time Light (NTL) index can interpret the level of economic vitality and activity in an area; the density of the highway network often reflects the extension of municipal services, the coverage of public transport, and the reach of the formal economy—the absence of highways indicates the spatial isolation of settlements, while the density of non-highway road (e.g., alleyway) networks is a manifestation of the community's self-organizing capacity and the result of the long-term operation of the dominant means of transport within the area; the NDVI index is a variable measuring environmental justice and ecological equity, representing residents' right to enjoy green public spaces and the survival risks of bearing ecological vulnerabilities.

3.2. Revelation of Main Drivers of Informal Settlements

This study employs a Multinomial Logistic Regression model to reveal determining characteristics by comparing multiple groups of formal and informal settlements. The analysis data comes from surveys and related data collection in the Bangkok urban area, comprising 99 valid samples. The analysis uses settlement type as the dependent variable and selects typical urban factors as independent variables. Descriptive statistical methods are first used to understand the overall distribution characteristics of the data. Subsequently, after standardizing the independent variables, a Nominal Regression (NOMREG) model is used for analysis. The significance of the influence of each factor is judged through the Likelihood Ratio Test, and the direction and strength of the influence are interpreted through the Parameter Estimates, ultimately obtaining the significant factors affecting the nature of urban settlements.

3.3. Study Area

This paper takes Bangkok, Thailand, as an example, selecting one informal settlement, one high-end settlement, and one traditional settlement to study the urban spatial characteristics and causes of informal settlements. Among Global South cities, Bangkok, as a major economic center and international metropolis in Southeast Asia, is an extreme case of unimodal urbanization. Its population and economic activities are highly concentrated, far exceeding those of Thailand's second-largest city. This rapid urbanization process has led to an explosive growth in housing demand, while the formal real estate market cannot provide affordable housing for low-income migrants, thus giving rise to a large number of informal settlements. These settlements are not only a housing problem but also a comprehensive reflection of urban governance, social equity, and economic development. The Khlong Toei area in Bangkok, one of the largest and oldest slums in Southeast Asia, is home to over 140,000 people living in substandard housing with limited rights and very limited access to public services such as healthcare, education, sanitation, and electricity, accompanied by high unemployment and crime rates. This situation is common and representative in Global South cities. Therefore, using Bangkok, Thailand, as the research object has strong typicality. As show in figure 1.

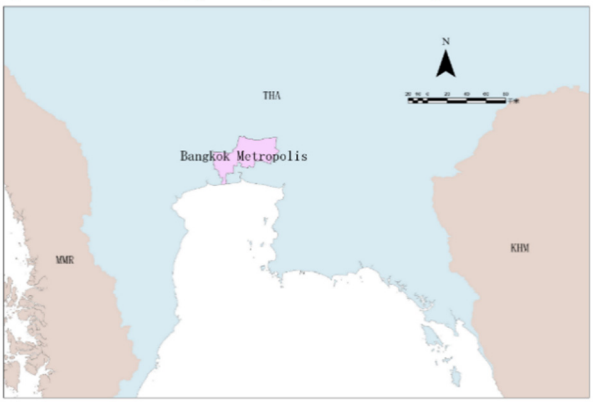

Figure 1. Study Area

3.4. Data Sources

The raster data in this study are all sourced from the Google Earth Engine online geospatial data processing tool. Road network data comes from the OpenStreetMap platform. Building data is sourced from the research article "3D-GloBFP: the first global three-dimensional building footprint dataset" by CHE Y Z, LI X C, LIU X P, et al.

4. Results and Discussion

4.1. Characteristic Analysis of Settlements in Bangkok

For effective comparative analysis, it is necessary to select typical areas within the same urban framework that have significant differences in socioeconomic status, built environment, and urban function. Based on this purpose, this study adopts a "typical case sampling" strategy, selecting three settlements within the Bangkok metropolitan area: the Sukhumvit-Thong Lo area representing high-end settlements, the Khlong Toei Slum area representing informal settlements, and the Ratchada-Phaya Thai area representing middle-income traditional settlements. As show in figure 2.

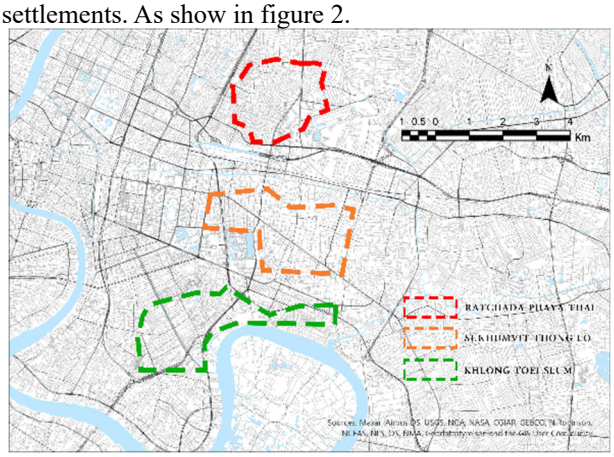

Figure 2. Location and extent of selected settlements

The Sukhumvit-Thong Lo area is a model of high-intensity capital development. Its urban fabric is marked by extremely high building density and vertical height, with high-rise condominiums and commercial buildings shaping Bangkok's most modern skyline. Correspondingly, this area exhibits high Night-Time Light brightness, reflecting its intensive economic activity. The road network density is high, and transportation infrastructure is well-developed.

In extreme contrast is the Khlong Toei Slum area. Here, a high-density but low-rise, disordered horizontal expansion pattern is present. The building footprint coverage approaches the limit, but most structures are low-quality and temporary. The formal road network density is low, replaced by narrow alleys impassable by motor vehicles. Although the overall economic level and infrastructure are poor, the Night-Time Light intensity is not significantly weakened. The NDVI values in this area are generally low, the public is extremely lacking in green public space, and the overall environmental quality is concerning, directly reflecting the informal spatialization of the city.

The Ratchada-Phaya Thai area, serving as a reference, presents a balanced, mixed intermediate state. Its building density and height are highly heterogeneous, with mid-to-high-rise apartments, commercial complexes, and public buildings coexisting. Moderately high Night-Time Lights and a good, effective road network density support its active but not extreme urban functions. The population density is high but within a reasonable range. Simultaneously, this area has considerable NDVI values, distributing concentrated green spaces like the Cultural Centre Plaza, reflecting a relative balance between development, vitality, and livability in a middle-income urban area.

4.2. Analysis of Determinant Characteristics of Informal Settlements in Bangkok

From the regression results, the p-value for Average Building Height is 0.000, indicating the most significant impact on settlement type; the p-value for Population Density is 0.001, indicating a significant impact; the p-value for Building Density is 0.006, indicating a significant impact; the p-value for Non-Highway Road Network Density is 0.058, approaching the significance level, indicating a marginally significant effect. In contrast, the Likelihood Ratio Test p-values for Road Network Density, Night-Time Light Index, NDVI, and HPF are all > 0.1, indicating no significant impact on settlement type.

It can be concluded that Average Building Height is the most significant predictor variable for identifying informal settlements. When the regional building height is at a low level (=1), the Odds of it being identified as an informal settlement are 664.2 times higher than for areas with a high level (=2) (B=6.499, p <0.001, 95% CI: 27.41--16096.47). Low-rise, dense small-scale buildings have long been regarded as the most prominent morphological feature of informal settlements. They are typically accompanied by irregular urban fabric, disorderly sprawling layouts, and narrow, winding alleys. This also implies that "informal settlement" is not merely a static land use type but rather a continuously self-evolving dynamic process—a special mode of forming high-density human settlements through bottom-up, self-organized methods outside formal institutions. In Bangkok, the building height factor essentially acts as a visual representation of capital investment. The densely standing luxury high-rises in the Sukhumvit area stand in sharp contrast to the low-rise, sprawling self-built housing in the Khlong Toei area. This disparity in the vertical dimension fundamentally exposes deep-seated structural inequality. Formal development relies on capital intensity and clear property rights, allowing it to compete for space vertically. In contrast, residents in informal settlements, lacking both capital and legal status, are forced to achieve extreme expansion of living space through densely arranged, low-cost, low-tech methods on limited land. This process almost inevitably results in a built environment characterized by high density, high coverage, and low publicness.

Population Density also demonstrates strong explanatory power, but its effect direction is opposite. The odds of a low population density area being identified as an informal settlement are only 0.017 times that of high-density areas (B=-4.079, p=0.004), meaning the odds significantly increase by approximately 58.8 times in high-density areas. The extremely high population density in Khlong Toei is not only a spatial feature but also a manifestation of a survival strategy. Bangkok, as a regional economic core, continuously attracts migrant workers from Cambodia, Laos, Myanmar, and elsewhere, who are systematically excluded from the formal housing market and consequently flock to urban fringe areas, splitting living costs by utilizing land to its limit. Therefore, high density is not merely physical crowding but also a social cost under economic exclusion. These areas gradually form large pools of low-income labor, collectively providing the city with a significant amount of cheap services.[8] However, this concentration continually reproduces its own marginality: cheap labor requires cheap accommodation, thereby constantly reinforcing the existence of such settlements.

Correspondingly, the high-density, non-standard road network system in informal settlements typically reflects their bottom-up formation logic lacking public planning support. These networks are not pre-designed on planning drawings but emerge spontaneously as passageways "squeezed out" during the constant densification of buildings to meet minimum access needs. These alleys, primarily for pedestrians and barely passable by motorcycles, while demonstrating a certain efficiency of self-organization, also starkly expose the severe lack of public goods provision: lighting, ventilation, clean water, public space, fire safety, social security, etc.[9]

Notably, the lack of significant correlation for traditional indicators like the Night-Time Light Index in these areas precisely maps the limitations of formal statistical tools when confronted with the informal economy. Even within informal settlements, based on the large population base, the night economy and informal businesses remain vibrant. This challenges the traditional paradigm of simply inferring economic levels based on light intensity, revealing the polymorphic and spatially fluid nature of economic activity.[10] Informal settlements are not blind spots of economic activity but rather host an economic ecosystem operating under a different, more disordered logic. The small vendors, difficult to capture with standardized data, actually undertake the function of supplying a large amount of cheap services for the city, especially in a highly tourism-dependent city like Bangkok, becoming an important livelihood source for the bottom-tier residents. However, this economic form always operates in the grey areas of policy, making it relatively more fragile.[11]

4.3. Implication for Urban Planning in the Global South

The empirical findings of this study extend beyond the context of Bangkok, offering critical insights for urban planning policy and intervention across the Global South. Planners and policymakers must move beyond viewing informal settlements merely as problems to be cleared or formalized, and instead recognize the underlying structural inequalities they represent.

First, the paramount significance of building height as a proxy for capital investment calls for a fundamental shift in planning focus from mere land use to the economics of vertical development. The stark contrast between low-rise informal settlements and high-rise formal areas underscores a systemic exclusion from the vertical city.[12] Planning interventions must therefore address the root causes of this exclusion. Instead of outright eviction, cities can explore granting secure, but perhaps incremental, land tenure or air rights that allow residents to safely invest in and gradually improve their housing, potentially enabling low-rise, high-density areas to evolve into more formal,

safer, and vertically consolidated neighborhoods over time. Mandating that private developers include a percentage of affordable housing units within their high-rise projects or offering them the right to build taller in exchange for providing public infrastructure or affordable housing can help break the mono-functional spatial segregation and integrate different income groups within the same urban fabric.

Second, the positive association between high population density and informal settlements highlights the critical need to manage density through service provision and infrastructure investment, rather than seeking to reduce density itself. Upgrading programs must focus on delivering core services—piped water, sanitation, electricity, and waste collection—to high-density informal areas.

Third, the marginal significance of the non-highway road network underscores the importance of recognizing and integrating self-organized urban fabric into the formal planning system. Instead of demolishing informal settlements to impose wide, formal road grids, planning should adopt a "retrofit" approach. This involves strategically upgrading these alley networks for improved accessibility for emergency services, enhancing pedestrian safety with lighting and paving, and formally integrating them into the city's broader non-motorized transport network.[13]

Overall, the ultimate goal of future planning is not only to change the physical appearance of these areas, but also to transform the planning process itself into a more adaptable, inclusive, and ultimately a tool for spatial justice. As show in table 1.

Table 1. Parameter Estimates

fclass[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
0	Intercept	-.830	2.149	.149	1	.700			
	[Pop Density=1]	-4.079	1.428	8.155	1	.004	.017	.001	.278
	Pop Density=2]	0[b]	.	.	0	.	.	.	.
	[Building Density =1]	1.414	1.177	1.443	1	.230	4.110	.410	41.250
	[Building Density =2]	0[b]	.	.	0	.	.	.	.
	[Avg Building Height=1]	6.499	1.626	15.966	1	.000	664.242	27.411	16096.472
	[Avg Building Height =2]	0[b]	.	.	0	.	.	.	.
1	Intercept	.772	2.222	.121	1	.728			
	[Pop Density=1]	-3.796	1.413	7.219	1	.007	.022	.001	.358
	[Pop Density=2]	0[b]	.	.	0	.	.	.	.
	[Building Density =1]	-.979	1.148	.727	1	.394	.376	.040	3.564
	[Building Density =2]	0[b]	.	.	0	.	.	.	.
	[Avg Building Height =1]	4.952	1.590	9.700	1	.002	141.398	6.268	3189.567
	[Avg Building Height =2]	0[b]	.	.	0	.	.	.	.

5. Conclusion

In summary, taking Bangkok as an example, the most significant features for identifying informal settlements are average building height and building density. From a social perspective, the fundamental distinction between informal and formal settlements lies in the former representing horizontal expansion and high-density, low-cost survival strategies under capital scarcity, while the latter embodies vertical growth and planned spatial production under capital intensity. This difference is not only morphological but also profoundly reveals the structural inequality in the distribution of urban spatial resources.

Simultaneously, this study establishes a model using a series of standardized urban indicators as independent variables and settlement type as the dependent variable. Other researchers can replicate the same analytical process in other major typical Global South cities like Jakarta, Lagos, or Mumbai. This allows research results from different cities to be objectively compared on the same dimension, enabling further investigation into whether the drivers of informalization are similar or distinct across different Global South megacities.

Furthermore, this model is essentially a predictive model. Planning departments can scan urban fringe areas or areas under development and calculate their likelihood of developing into informal settlements. Areas possessing high-risk characteristics can be identified, allowing for the suppression of disorderly sprawl of informality at its source before problems erupt.

However, this study has certain limitations. Firstly, the size and number of sample grids limit the generalizability of the conclusions. Future research could expand the sample size and conduct cross-city comparisons. Secondly, the independent variables are mostly concentrated on the morphological level and do not involve institutional, socio-economic, or other deep-seated driving factors. Additionally, cross-sectional data makes it difficult to capture the dynamic process of informalization, and the linear assumption of Logistic Regression might oversimplify the complex relationships between variables. Future research could incorporate multi-source non-morphological data and combine it with machine learning models capable of handling non-linear relationships for comparative verification, aiming to more comprehensively and profoundly reveal the influencing factors and mechanisms of informal settlements.

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