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A Comparative Study of SMAA-VIKOR and SMAA-TOPSIS in Urban Redevelopment Potential Evaluation in Guangzhou: Effectiveness and Spatial Insights

Estudio comparativo de SMAA-VIKOR y SMAA-TOPSIS en la evaluación del potencial de reurbanización urbana en Guangzhou: eficacia y perspectivas espaciales

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Resumen

Keywords:
renewal potential
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Urban renewal decision-making involves balancing complex and often conflicting spatial, environmental, and socio-economic factors. This study compares two stochastic multi-criteria decision-making methods—SMAA-VIKOR and SMAA-TOPSIS—to evaluate community-level redevelopment potential in Guangzhou's central urban area. By constructing a comprehensive evaluation framework that includes land and building characteristics, public service coverage, environmental quality, and socio-economic conditions, this study adopts the two algorithms to categorize 912 communities into four levels of renewal potentials and compare their performance by validated redevelopment projects' sites. The result shows that SMAA-VIKOR yields more accurate and spatially coherent classifications, with 83% of projects located in high or medium potential zones, compared to 50% under SMAA-TOPSIS. It reveals that SMAA-VIKOR better captures trade-offs among indicators and provides a more balanced and policy-relevant basis for prioritizing renewal interventions. This research contributes a robust, scalable framework for data-driven urban renewal evaluation and offers practical insights for cities aiming to integrate spatial analytics into planning decisions under uncertainty.

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Abstract

Palabras clave:
evaluación del potencial de
renovación; renovación
urbana; MCDM; Big data

La toma de decisiones en la renovación urbana implica equilibrar factores espaciales, ambientales y socioeconómicos complejos y a menudo conflictivos. Este estudio compara dos métodos estocásticos de toma de decisiones multicriterio—SMAA-VIKOR y SMAA-TOPSIS—para evaluar el potencial de regeneración a nivel comunitario en el área central urbana de Guangzhou. Al construir un marco de evaluación integral que incluye características del suelo y los edificios, la cobertura de los servicios públicos, la calidad ambiental y las condiciones socioeconómicas, este estudio adopta ambos algoritmos para clasificar 912 comunidades en cuatro niveles de potencial de renovación y comparar su rendimiento con sitios de proyectos de renovación validados. Los resultados muestran que SMAA-VIKOR genera clasificaciones más precisas y espacialmente coherentes, con un 83% de los proyectos ubicados en zonas de alto o medio potencial, en comparación con el 50% bajo SMAA-TOPSIS. Esto revela que SMAA-VIKOR captura mejor los compromisos entre los indicadores y proporciona una base más equilibrada y relevante para las políticas para priorizar las intervenciones de renovación. Esta investigación contribuye con un marco robusto y escalable para la evaluación de la renovación urbana basada en datos y ofrece ideas prácticas para las ciudades que buscan integrar el análisis espacial en las decisiones de planificación bajo incertidumbre.



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1. Introduction

Urban renewal is a comprehensive and holistic approach to addressing urban issues, aiming to achieve continuous improvement in economic, social, and physical environmental aspects of renewal areas (Roberts, 2000). Unlike most developed countries, where urban infrastructure has been modernized, cities in developing nations often face structural inefficiencies of land use, aging buildings, and unbalanced spatial arrangement due to the accelerated urbanization process. In many megacities, particularly in China, historical districts, industrial zones, and informal settlements coexist with modern urban expansion, thus generating complex urban renewal needs in these cities.

Following the Reform and Opening-up policy in 1978, the rapid urbanization has led to significant growth of urban areas in both volume and structure. Concurrently, expansion has produced challenges such as insufficient public space and deteriorating environmental quality in the traditional city center.

Therefore, the regeneration of urban central districts is at the core of China's urban renewal initiatives (Yang, 2020). Thus, assessing the renewal potential plays a crucial role in guiding and implementing urban renewal efforts. It can help decision-makers to prioritize where to intervene first and what to fix. More importantly, a well-designed assessment strengthens policy effectiveness. It can align renewal projects with the arrangement of urban land resources and improve the transparency and measurability of renewal goals and outcomes.

Although evaluation indicator systems vary from studies (Xu et al., 2022), some dimensions are in common: such as location factors (J Wang et al., 2019), public services, the built environment quality (Wang et al., 2020) and socio-economic conditions (Liang et al., 2018). However, most potential assessments fail to consider the impact of renewal costs due to difficulties of data acquisition.

In terms of methodology, current evaluations of urban renewal potential primarily rely on methods such as the analytic hierarchy Process (AHP) (Jia et al., 2024), the Delphi method (Cai et al., 2024), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (J Wang et al., 2019). However, the AHP or Delphi method includes strong subjectivity and lacks of correlation analysis between indicators, which affect the accuracy and stability of comprehensive assessments (Zhu et al., 2020). TOPSIS provides a spatial-characteristic based ranking process but lacks robustness in handling the weight uncertainty. Therefore, a critical challenge in recent research is how to leverage open-source data to represent the renewal cost and investigate better assessment methods to improve the precision of urban renewal evaluation results.

Therefore, this study takes the central urban area of Guangzhou as the study case, to identify communities' urban renewal potential utilizing a stochastic weight and multi-criteria method while introducing the renewal cost dummy variables. In concrete, we perform a comparative analysis among SMAA-VIKOR (Stochastic multi-objective acceptability analysis -VIKOR) (Opricovic & Tzeng, 2004), SMAA-TOPSIS (Okul et al., 2014) and the traditional TOPSIS in assessing urban renewal potential at a community level.

Finally, the study compares the effectiveness of these methods using the validated urban redevelopment projects obtained from the official land approval database and planning documents. The result shows that the renewal potential in Guangzhou's central urban areas generally decreases outward from historical districts, aligning with urban expansion trends. Compared to other methods, the SMAA-VIKOR model achieves a higher accuracy in general, especially in low potential communities. It implies that pre-screening urban renewal potentials through quantitative methods is of a certain practical effectiveness, especially when the features are distinctly different. Moreover, we clarify how prioritization changes across aggregation rules under different methods, thereby improving the interpretability of algorithms under the scenario of urban renewal potential evaluation.

The arrangement of the article is as follows: the literature review summarizes indicators and methods for the evaluation of urban renewal potential, followed by an introduction to the SMAA variants. Section 3 explains the research design and introduces data sources, indicator selection, and details of implementation steps for SMAA-VIKOR, SMAA-TOPSIS, and TOPSIS. Section 4 analyzes the spatial characteristics of urban renewal potential at a community level and compares the ranking accuracy of the three methods against the location of confirmed redevelopment projects. Finally, Section 5 synthesizes key findings and proposes suggestions for future research.

2. Literature Review

2.1. Assessment of urban renewal potential

The definition and criteria for assessing urban renewal potential have not formed a unified standard. The understanding of renewal potential varies in different countries due to different urban development priorities, governance structures, and socio-economic conditions (De Gregorio Hurtado, 2023). In developed countries, the research mainly focused on the sustainability of urban regeneration, emphasizing the integration of environmental, social, and economic dimensions (Escobar Ramírez (2024)). For example, Hemphill et al. (2002) developed the sustainability indicators that included economic and employment factors, resource utilization, building, land use, and community benefits. In the study of the sustainable renewal of abandoned urban areas in Europe, Laprise et al. (2015) proposed an evaluation framework encompassing three major dimensions: the built environment, socio-cultural aspects, and the economic conditions. The study emphasized that merely increasing development intensity was insufficient to achieve long-term sustainability. Zhao et al. (2023) constructed a comprehensive model of urban renewal evaluation incorporating social, economic, environmental, and governance dimensions. Using the Delphi method, the study concluded that social factors have the most significant impact on achieving sustainable urban renewal; while building and land use indicators held the highest weights in the evaluation system.

In contrast, studies in developing countries typically emphasized spatial reallocation, land use, and infrastructure improvement. In China, the evaluation of urban renewal potential can be categorized into two types based on the dimension. The single-dimensional evaluation mainly focused on a specific urban issue. For instance, Zhang et al. (2004) assessed the renewal potential of Nanjing based on land use status, including the land intensity, structure, and economic value. Wu et al. (2021) measured renewal potential in enterprise communities by the availability of redevelopment areas and the scope for intensifying development. Other work utilized the status of building facade (Bai et al., 2023) or the deficiency of public facilities (Tan, 2017) to estimate the renewal potential.

The second type of evaluation assesses urban renewal potential from a comprehensive perspective, such as renewal demands, redevelopment values, and feasibility. For instance, Jingli Wang et al. (2019) used locational conditions, completeness of public facilities, and building intensity as key indicators to identify the renewal potential. Cui (2024) analyzed the renewal demand through the lens of community-level public service provision and employed cluster analysis to assess the renewal potential of Linxia's central urban area in Gansu Province. Lin (2019) proposed a six-dimensional evaluation framework for old town regeneration, covering historical and cultural value, economic cost factors, environmental and locational advantages, public service efficiency, and transportation accessibility. Based on empirical experiences in Xiamen, Xu et al. (2022) constructed a coastal urban renewal potential model incorporating location and transportation accessibility, spatial characteristics, and tourism resource values. Luo et al. (2023) developed a two-dimensional evaluation framework, focusing on both the necessity and feasibility of redevelopment. The necessity dimension includes factors such as the inefficiency of land use, public willingness to renew, and the alignment with planning goals, while the feasibility dimension considers land development conditions, scale, value, and other supportive indicators.

In sum, the existing frameworks largely revolve around two dimensions: (1) the renewal demand, such as the adequacy of public facilities, land use efficiency, and aging buildings; (2) the renewal value, including locational advantages, resource endowment, and economic potential. While these dimensions provided a solid foundation for evaluating renewal priorities, many assessments overlooked the constraints imposed by renewal costs, particularly the complex stakeholder interests, institutional barriers, and high financial investment requirements (Jia et al., 2024). Although some scholars have utilized the complexity of land property rights (Jingli Wang et al., 2019) as a proxy variable, the non-disclosure of land registration data limited the feasibility of this indicator. Therefore, it is necessary to find more holistic approaches that can represent implementation constraints.

Regarding analytic approaches of identifying the renewal potential, common methods include Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Wu et al., 2021), cluster analysis (Jiang et al., 2023), and comprehensive analysis (Cai et al., 2024). Despite its popularity, TOPSIS is notably sensitive to the assignment of criterion weights. Small perturbations can reverse the ordering, especially when alternatives are closely matched. Moreover, in situations where trade-offs exist—such as between increasing building intensity

and preserving green space—the method may struggle to deliver a balanced compromise, potentially leading to biased or unstable ranking outcomes (Tzeng & Huang, 2011).

In the scenario of urban renewal, the areas to be regenerated usually need to balance multiple goals and resources, thus, it is necessary to introduce more flexible and robust methods that can accommodate the weight uncertainty and conflicting objectives in urban renewal potential evaluation.

In addition, the macro-scale detection of urban renewal potential usually adopted grid cells or land parcels as the basic spatial units (Xu et al., 2022), which were subsequently aggregated and analyzed by districts or streets (Wang et al., 2020). However, according to the practical governance process, the community is the basic working units of urban renewal projects. The community office oversees delivering policies, monitoring the operation of projects and collecting feedback.

Therefore, the misalignment between assessment units and operational realities may affect the practical applicability of existing evaluation frameworks. It is better to realign the assessment framework with the actual governance and implementation structure by setting the community as the evaluation unit, therefore enabling the coupling of spatial diagnostics with administrative feasibility and social responsiveness.

In summary, current methods for assessing urban renewal potential still present limitations, particularly in the areas of weight assignment strategies, cost indicator integration and spatial measurement units, and. For solving the research gap, we propose a comparative framework that identifies the urban renewal potential via TOPSIS, SMAA-VIKOR and SMAA-TOPSIS. In this way, the robustness and stability of evaluation methods can be explicitly examined.

2.2. Stochastic multi-criteria acceptability analysis

Stochastic multi-criteria acceptability analysis (SMAA) is a family of methods designed to handle the complexities and uncertainties inherent in Multiple-criteria decision analysis (MCDM) (Lahdelma et al., 1998). Unlike traditional approaches that assign a fixed weight for each criterion, SMAA tackles the problem of uncertainty or missing preference information by stochastic sampling over the weight space. It avoids the subjective bias and insufficient consideration of information that may arise from traditional fixed weighting, thus it fits better in complex decision-making scenarios (Kim & Ahn, 2020). For example, Rocchi (2012) used SMAA in the Management Plan of Trasimeno Park incorporating with political and social context.

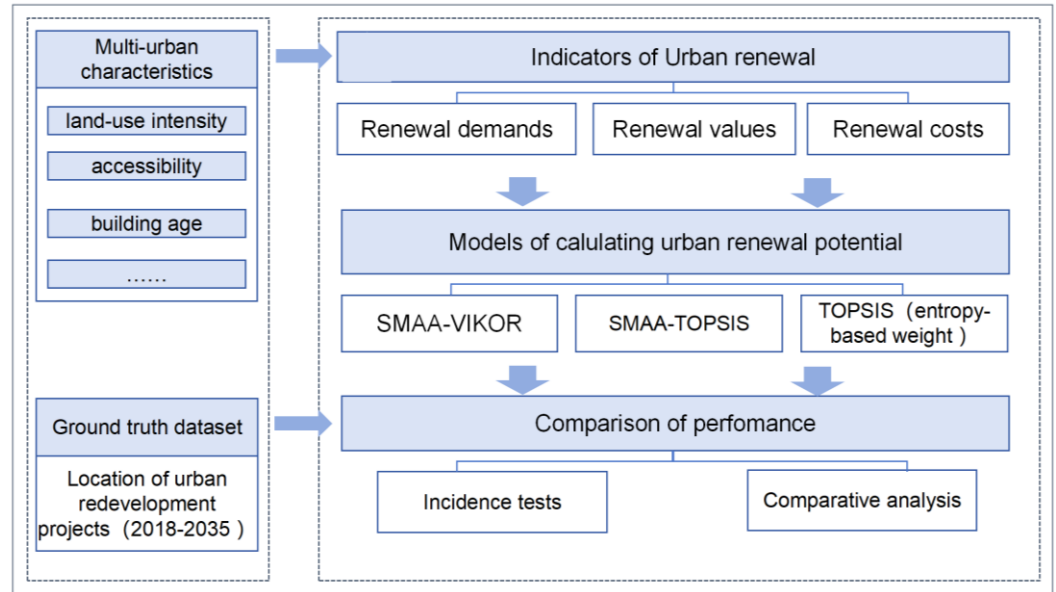
Researchers have also proposed hybrid methods that combine SMAA with established ranking techniques to improve both interpretability and performance, such as SMAA-VIKOR (Aydogan & Ozmen, 2017) and SMAA-TOPSIS (Okul et al., 2014). The SMAA-TOPSIS method integrates the geometric distance logic of TOPSIS with the stochastic weight exploration of SMAA, allowing alternatives to be ranked probabilistically relative to stochastic ideal and anti-ideal points in multi-criteria space. Such hybrid approaches have been applied in areas like drug benefit-risk analysis and machine gun selection (Okul et al., 2014). Different from the “polarized solution” of TOPSIS, VIKOR considers the ideal solution based on a compromise among multiple criteria by balancing individual and group regret measures (Opricovic & Tzeng, 2004).

Some work has applied SMAA-VIKOR to reservoir flood control decision (Xu et al., 2023) and the planning of wind–photovoltaic–hydropower systems (Liu et al., 2024). Collectively, these studies indicate that SMAA and its hybrids are well suited for multi-criteria evaluations where preferences are uncertain and trade-offs must be communicated through robustness and acceptability information rather than deterministic rankings.

3. Data and Methods

This study proposes a three-stage methodological framework for assessing urban-renewal potential in Guangzhou's central districts (Figure 1). First, a multi-indicator system is constructed in terms of renewal demands, benefits, and costs. Pearson correlation analysis is employed to characterize inter-indicator structure and identify potential collinearity for cautious interpretation. Second, SMAA-VIKOR and SMAA-TOPSIS are implemented and benchmarked against the traditional TOPSIS method with entropy-derived fixed weights. We evaluate the performance of the three algorithms against a ground truth dataset of redevelopment projects. Finally, the effectiveness is assessed by the incidence test, which quantifies the number of verified urban redevelopment projects located within the higher-rank segment of each algorithm.

Figure 1 Research Framework

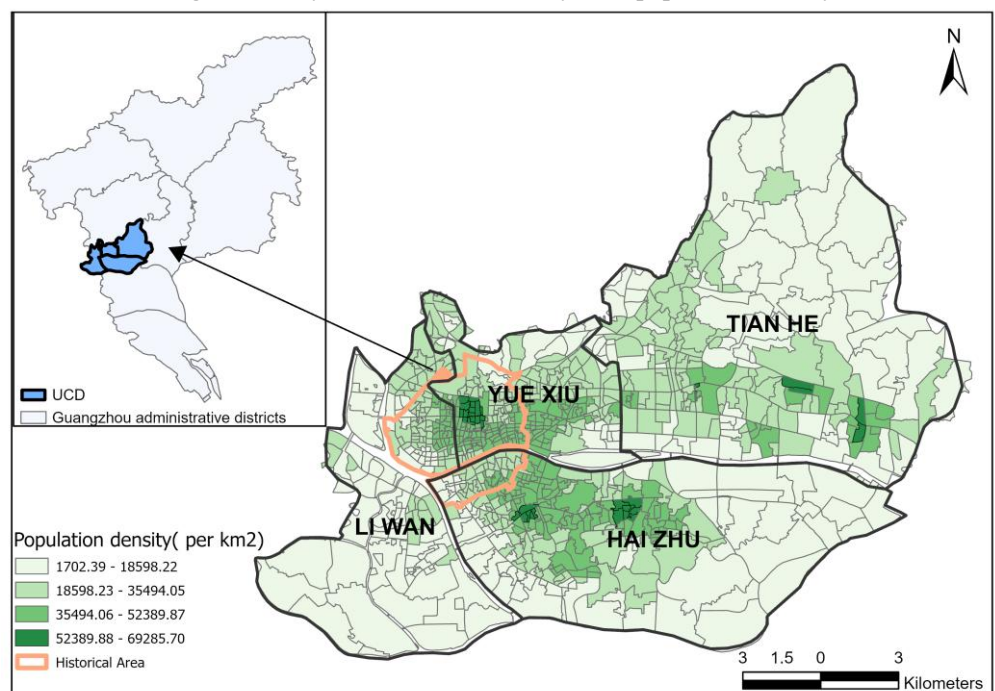


Source: own elaboration

3.1. Study Area

Guangzhou, the capital of Guangdong Province in southern China, is a key megacity and economic hub within the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). Covering an area of approximately 7,434 km², it has 11 districts in total and supports more than 18 million people. As a rapidly growing metropolis, Guangzhou has undergone extensive urban expansions over the past few decades. However, the central urban district(UCD), which includes Yuexiu, Liwan, Haizhu, and Tianhe districts, faces significant challenges such as the extremely high density of population, lower environmental quality, and aging infrastructures (Ye et al., 2024). It has a total of 912 communities (Figure 2) in which many traditional neighborhoods, historical areas, and obsolete industrial zones require redevelopment to accommodate demands of a livable city. For example, according to the *2023 Guangzhou Statistical Yearbook*, the total area of the urban central area is 279.63 km², with a permanent population of 6.17 million, accounting for about 32.95% of the total population of the city. The average population density exceeds 20,000 people per km²; some communities even exceed 40,000 people per km². Therefore, Guangzhou is representative among Chinese megacities as a case study for urban renewal potential assessment.

Figure 2 Study area with a community-level population density



Source: own elaboration

3.2. Data sources and processing

Table 1 lists data sources and their corresponding year of production. The resident population utilized the mobile signaling data from China Unicom because the official Yearbook only provides the number of populations at the district level. The dataset was 100×100-meter grid format, which was overlaid with community boundaries to obtain the total residential population of each community. Public facilities were extracted from POIs (Point of Interests) of Amap. The Construction land area was extracted from the land use dataset of the Chinese Academy of Sciences, covering three periods: 1980, 2000, and 2015. The boundary of urban villages was identified through high-resolution remote sensing data, following the method of Chen and Zhuang (2020), and manually verified. The remaining data were gathered from the official open data.

Table 1 Data sources

Data name	Data Source	Year
Community administrative divisions	National Bureau of Statistics	2020
Resident population	Mobile signaling from China Unicom company	2022
Housing price data	Anjuke website: https://guangzhou.anjuke.com/	2022
Medical and commercial services, subway stations, park and green space	Amap POI data: https://lbs.amap.com/	2022
Building footprints	OpenStreetMap	2022
Urban villages	Sentinel-2 remote sensing data	2022
Construction land	China Multi-period Land Use Remote Sensing Monitoring (CNLUCC) Dataset	1980\2000\2015
Annual average temperature, average air quality index	"China Surface Meteorological Observation Historical Dataset", "National Urban Air Quality Report"	2022
Historical urban area	<i>Guangzhou Historical and Cultural City Protection Plan (2021-2035)</i>	/
"Three old" land area	"Three Old" land-use database	2018
Urban redevelopment projects	The "Three Old" Renovation Involving Land Use Approval Status Table from 2018 to 2025 <i>Guangzhou Urban Renewal Special Plan (2021-2035)</i> : list of comprehensive renovation and mixed renovation and renewal projects for old villages and towns in Guangzhou from 2021 to 2035	/

Source: own elaboration

The renewable land data was from the "Three Old" land use database of Guangzhou, which refers to areas of old towns, old factory buildings, and old villages. To validate the evaluation results, we compiled a dataset of 61 officially confirmed urban redevelopment projects (2018–2023) from two authoritative sources: (1) the "Three Old" land-use approval records and (2) the Guangzhou Urban Renewal Special Plan (2021–2035). The "Three Old" land-use approval records document administratively approved redevelopment projects, typically involving the conversion of collective construction land to state-owned land and the completion of formal procedures such as land acquisition and related approvals (Urban Renewal and Land Consolidation Office, 2023). The Guangzhou Urban Renewal Special Plan (2021–2035) provides a planning-level project list, including renewal initiatives for old villages and towns, and classifies them into comprehensive renovation and mixed renovation. In this plan, "comprehensive renovation" refers to projects dominated by demolition, reconstruction, or redevelopment, whereas "mixed renovation" combines partial reconstruction with micro-renewal measures, such as façade improvement of existing buildings and upgrading public-space landscapes. These two sources were selected because they jointly cover both implemented/approved and strategically planned redevelopment projects, ensuring that the validation sample is policy-relevant and representative of Guangzhou's current urban renewal practice.

3.3. Indicators of urban renewal potential

Taking communities as the unit of analysis, this study establishes a comprehensive urban renewal potential assessment indicator system, structured around three dimensions drawn from the existing studies: renewal demand, renewal value, and renewal cost (Table 2).

Firstly, the renewal demand encompasses five characteristics of communities: the density of residents, building status, the temporal distribution of construction land, quality of the ecological environment, and public services. Higher population density typically signals increased pressure on infrastructure and services, thereby indicating a stronger need for renewal interventions. The building-related indicators include building density, average building height, and the proportion of urban villages, which together reflect the physical intensity and structural age of the built environment. Communities with higher building density and a larger share of urban villages are generally considered to have a higher need for urban renovation. In contrast, building height is a reverse indicator, since taller buildings are usually newer, and thus associated with lower renewal urgency.

Table 2 Characteristic indicators of urban renewal potential assessment

Dimensions	Feature	Indicator name	Calculation formula	Indicator Description
Renewal demands	Demographic condition	Average residential population density (person/km ²)	Community population / community area	Positive
	Building features	Average building density	Building base area/community area	Positive
		Average building height (m)	Average height of community buildings	Negative
		Area ratio of urban villages (%)	Urban village area/community area	Positive
	Ecological environment	Average annual temperature (°C)	/	Positive
		Annual average air quality index		Positive
	Land use	Proportion of construction land before 1980 (%)	The correspondent land area/community area	Positive
		Proportion of construction land from 1980 to 2000 (%)		Positive
		Proportion of construction land from 2000 to 2015 (%)		Negative
		Proportion of “Three old” land (%)		Positive
	Public services	The proportion of total community area covered by medical facilities within 1,500 meters (%)	1500m buffer area of the facility /total area of the community	Negative
		The proportion of the total area of the community covered by park green space within 1,500 meters (%)		Negative
		The proportion of total community area covered by commercial facilities within 1,500 meters (%)		Negative
Renewal value	Economic value characteristics	Average price of second-hand houses (Yuan/m ²)	Average price of second-hand houses for sale in the community	Positive
	Traffic location characteristics	The proportion of total community area covered by subway stations within 1,500 meters (%)	1500m buffer area of the facility /total area of the community	Positive

	Historical and cultural value characteristics	In/out the historic district	If the community is in the historical district, the value is 1; otherwise, the value is 0	Positive
Renewal cost	Economic cost (dummy variable)	The average price of second-hand houses in the extremely high range	If it is in the extremely high value range, it takes 1; otherwise, it takes 0	Negative
		The residential population density in the extremely high range		Negative

Source: own elaboration

A notable type of building in Guangzhou is the urban village (“Cheng zhong cun” in Chinese pinyin), which is a kind of high-density, self-built settlement embedded within the modern urban fabric (Figure 3). Originally, they were rural settlements near the city center. Therefore, unlike the planned urban neighborhood, urban villages maintain collective land ownership. Due to issues of property rights and resettlement, many urban villages have not been able to be renovated or redeveloped. These urban villages typically feature dense clusters of low- to mid-rise buildings, narrow internal streets, and a mix of informal residential and commercial functions. These features make urban villages a critical spatial focus in the city’s renewal agenda due to their structural obsolescence, service deficiencies, and higher building safety problems.

Figure 3 A parcel of urban villages (left) v.s. modern residential parcel (right) in Guangzhou



Source: own elaboration

Land characteristics contain two indicators: the development period and the extent of renewable land. The development period is inferred by historical construction land data, with earlier periods typically associated with aging infrastructure and, consequently, greater renewal demand. The renewable land component is from Guangzhou’s official “Three Old” land-use database, which includes old towns, old factories, and old villages. Since 2009, Guangzhou has implemented a “mapping and database registration” policy, under which only land parcels included in this registry are eligible for urban renewal projects (Tang & Yang, 2018).

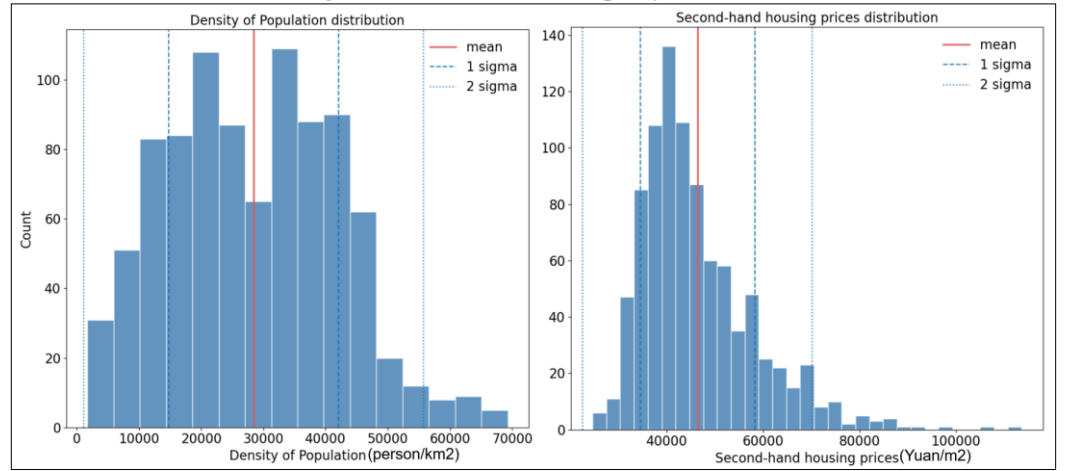
Public service accessibility is captured through the coverage of medical facilities, urban green spaces, and commercial services. These indicators are negatively correlated with the renewal demand because communities with better public services tend to have lower urgency for redevelopment. Ecological environmental quality is composed of two indicators: the annual average temperature and the Air Quality Index (AQI). In line with the increasing policy emphasis on green and sustainable urban development, these environmental factors are also incorporated into the assessment framework to reflect the growing relevance of ecological quality in shaping urban renewal priorities.

Renewal value is composed of three dimensions: historical and cultural value, transportation accessibility, and economic value. Historical and cultural value is represented by whether a community is located within the historic district, which reflects its preservation significance and the potential for renewal projects. Transportation accessibility is measured by the proportion of the community’s area located within a 1,500-meter radius of a metro station. According to current planning guidelines, areas surrounding metro stations are typically subject to higher development intensity; these places usually have higher investment values

(Rong et al., 2023). Moreover, the average price of second-hand housing is also an indicator of renewal value. Higher housing prices indicate stronger real estate market performance and greater potential for value appreciation after redevelopment(Wang et al., 2020).

Regarding renewal costs, the model introduces extremely high population density and second-hand housing prices as proxy variables. These indicators reflect the practical challenges associated with redevelopment: areas with higher population density often entail more complex coordination among stakeholders, while higher housing prices typically correspond to increased compensation and investment requirements. To operationalize this dimension, a threshold-based segmentation method is applied. The segmentation is based on the mean value plus one standard deviation (sd.) as the cut-off point, dividing the data into two categories: the extremely high value segment ($>\text{mean}+1\text{sd.}$) and non-extremely high value segment ($\leq\text{mean}+1\text{sd.}$). We do not test more thresholds because the distribution of these two variables is not symmetric (Figure 4), which causes the location of 2sd. to be out of the data range on the left side. The extremely high-value segment is assigned a negative relationship with renewal potential relationship with renewal potential, meaning that as population density and housing prices exceed the threshold, the feasibility of renewal diminishes due to elevated social and economic costs.

Figure 4 The Distribution of proxy variables



Source: own elaboration

3.3. Computation Methods

3.4.1 Characteristics of urban renewal indicators

Firstly, this study computes Pearson correlation coefficients among all indicators to uncover salient inter-indicator associations underlying renewal potential in the central area. This step helps identify both positive and negative linear relationships for informing subsequent interpretations. The formula is as shown in Eq. (1):

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{(\sum_{i=1}^n (X_i - \bar{X})^2) \sum_{i=1}^n (Y_i - \bar{Y})^2}} \quad (1)$$

where r is the correlation coefficient between indicators, X , Y are the indicator values of community i .

3.4.2 SMAA-VIKOR, SMAA-TOPSIS and TOPSIS

For easier comparison, Figure 5 illustrates the computation process of SMAA-VIKOR, SMAA-TOPSIS and TOPSIS. All three procedures share a common preprocessing stage: indicators are direction-aligned and normalized to ensure commensurability across criteria. In the SMAA variants, criterion measurements remain fixed, while weights are sampled from the admissible weight space at each iteration through the Monte Carlo method.

For each sampled weight vector, VIKOR and TOPSIS are executed and produce a rank order, separately. Aggregating results over iterations yields a rank acceptability index which summarizes the ranking stability under different weights. In contrast, the traditional TOPSIS employs a fixed-weight vector, generating a single deterministic ranking. The calculation of algorithms is explained as follows:

(1) Weight Calculation

Step1: Define the criteria and utility space: take the community renewal potential index as the criterion $\{g_1, \dots, g_j, \dots, g_n\}$, then define the community as different schemes $X = \{x_1, \dots, x_i, \dots, x_m\}$. The renewal potential of each community is considered as the utility U , which is determined by the convex combination of each criterion and its corresponding weight, denoted as $U(x_i, w) = \sum_{j=1}^n w_j g_j(x_i)$.

Step2: Generate the weight vector: weight vectors are randomly generated from the weight space using Monte Carlo method. The weight space assumes that all weights are non-negative and their total sum equals 1, which is defined as Eq. (2):

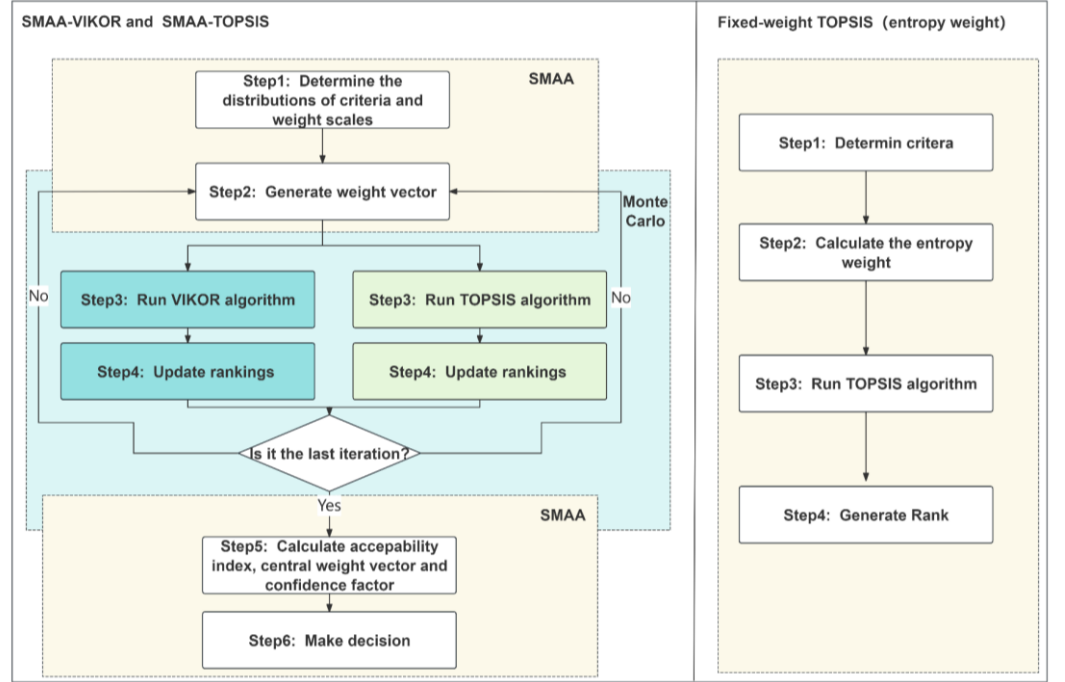
$$W = \left\{ w \in R^n : w \geq 0 \text{ and } \sum_{j=1}^n w_j = 1 \right\} \quad (2)$$

the optimized weight set is selected from the set of alternatives with higher total utility, which is expressed as Eq. (3):

$$W_i(g) = \{w \in W : u(x_i, w) \geq u(x_k, w), \forall k = 1 \dots m\} \quad (3)$$

In contrast, the fixed-weight TOPSIS method whose weight are determined by the entropy weight method (Zhu et al., 2020).

Figure 5 The framework of the algorithm



Source: own elaboration

(2) Ranking calculation

(a) VIKOR method: For each alternative, the maximum (g_j^+) and minimum values (g_j^-) of each criterion (g_{ij}) are determined as the positive and negative ideal solutions. Therefore, we can calculate the total deviation of an alternative from the ideal solution S_i , the maximum deviation of an individual criterion R_i , and the comprehensive evaluation score Q_i . Detailed formulas are given in Eq.(4)-(6) :

$$S_i = \sum_{j=1}^n w_j \frac{g_j^+ - g_{ij}}{g_j^+ - g_j^-} \quad (4)$$

$$R_i = \max \frac{g_j^+ - g_{ij}}{g_j^+ - g_j^-} \quad (5)$$

$$Q_i = v \frac{S_i - S_{imin}}{S_{imax} - S_{imin}} + (1 - v) \frac{R_i - R_{imin}}{R_{imax} - R_{imin}} \quad (6)$$

In the ranking formular Q , ν is a strategy coefficient ranging between 0 and 1, used to adjust the weight distribution of factors in the model. Following previous studies, this research sets ν to 0.5. The final ranking of alternatives is determined based on the Q value—a smaller Q value indicates a closer distance to the ideal solution, resulting in a higher ranking, which signifies greater urban renewal potential for the community.

(b) TOPSIS method: the core concept is to select the alternative that is closest to the ideal solution and farthest from the negative ideal solution as the optimal choice (Eq. (7)):

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (7)$$

where D_i represents the Euclidean distance between alternative i and the positive and negative ideal solutions. C denotes the closeness coefficient to the optimal solution—the higher the C value, the higher the ranking.

(c) Ranking output

For the SMAA variants, we set 10,000 iterations to updating weights and ranks for producing the rank distribution. The final ranking is obtained from the acceptability index, which represents the probability that a given community occupies a particular rank across all weight scenarios (Eq. (8)):

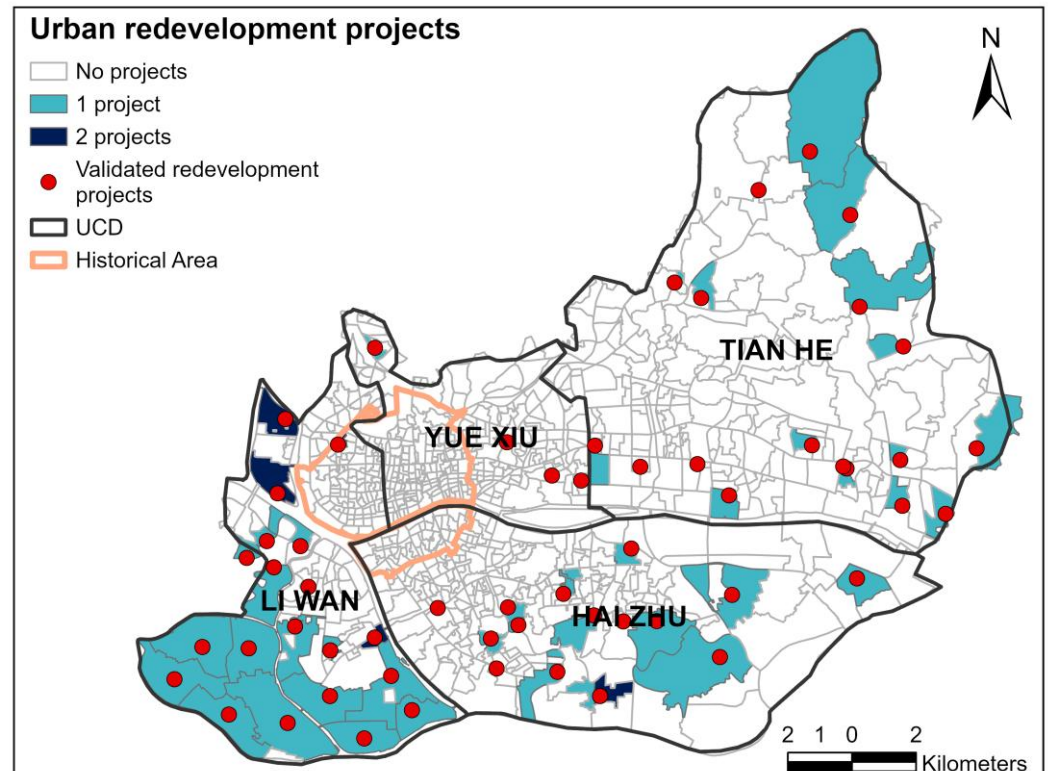
$$b_i^r = P(\text{rank}_i = k) \quad (8)$$

interpreted as the probability that alternative i attains rank k under the modeled weight. A higher acceptability index means that the community is more likely to hold that rank position. On the other hand, the fixed-weight TOPSIS conducts the single rank directly.

3.4.3 Comparison of rankings

For easier comparison, rankings are divided into four equal intervals, which categorize different renewal potential levels from high to low. It enables an intuitive visual analysis of their spatial distribution patterns. The spatial distribution of validated redevelopment projects within these categories serves as a ground-truth reference to evaluate and validate the effectiveness of the renewal potential assessment provided by each algorithm (Figure 6). Validated redevelopment projects are rarely found in historic urban areas because the current urban redevelopment policies in China, which primarily focus on “micro-renewal” or protective restoration in the historical area, rather than large-scale reconstruction projects. This study failed to provide all types of urban renovation projects due to the availability of open-source data.

Figure 6 Locations of urban redevelopment projects



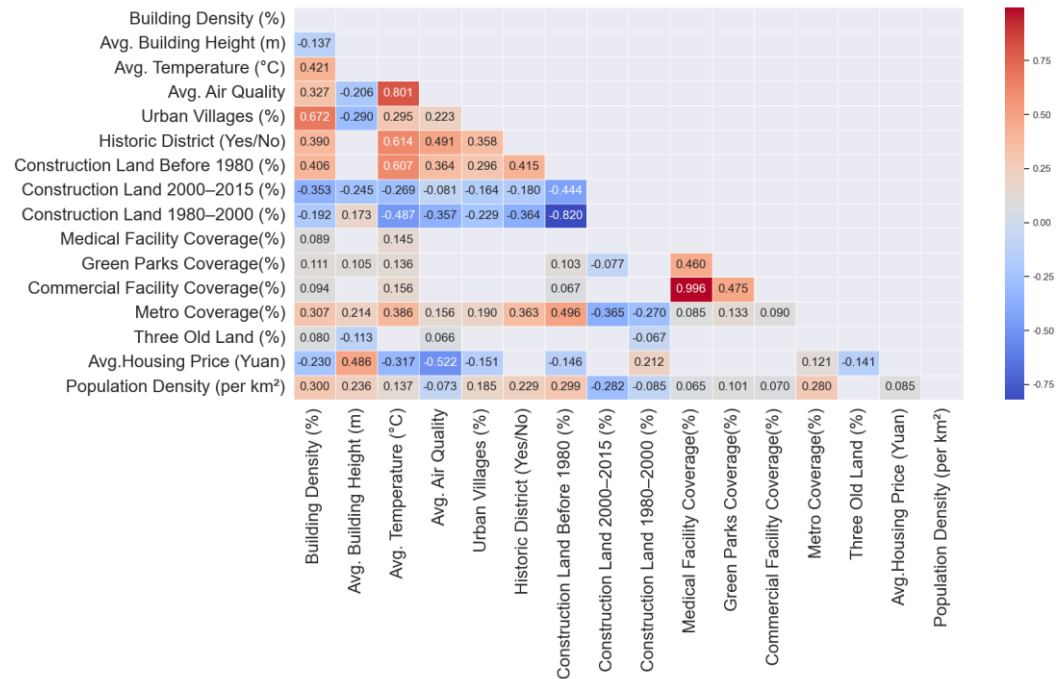
Source: own elaboration

4. Results

4.1. The characteristics of renewal potentials in the central urban area of Guangzhou

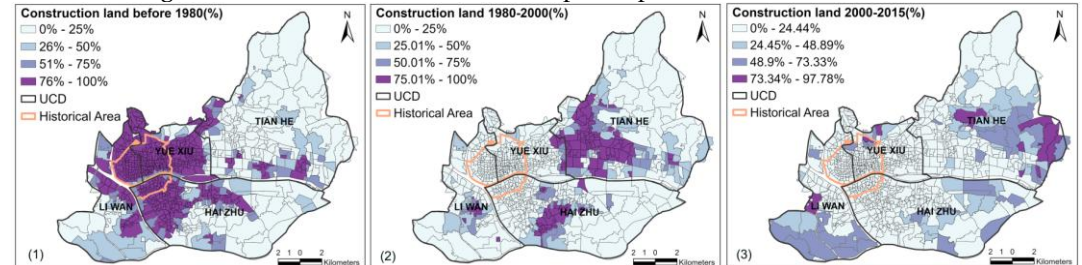
Firstly, regarding land use characteristics, the spatial distribution of construction land across different development periods demonstrates a clear pattern of spatial exclusivity (Figure 7) indicating the spatial trajectory of urban expansion. Before 1980, the construction land in Guangzhou was concentrated in the Yuexiu and Liwan districts, which were also the historical urban area (Figure 8). Following the launch of China's reform and opening-up, urban expansion accelerated, with new construction spreading outward from the historic city center, particularly in eastern and southwestern directions. Between 1980 and 2000, the Tianhe and Haizhu districts experienced substantial growth in construction land areas, reflecting the shift in urban development focus. After 2000, the momentum of regional integration, especially the development of the Guangzhou–Foshan metropolitan area, further propelled urban expansion into the southern zone of Liwan District, which borders Foshan. This area subsequently witnessed a marked increase in construction activity, driven by inter-city connectivity and cross-boundary development.

Figure 7 Heat map of Pearson correlation coefficient among indicators



Note: only the significant shows one the heat map (p-value < 0.05). Source: own elaboration

Figure 8 Distribution of different development periods of construction land

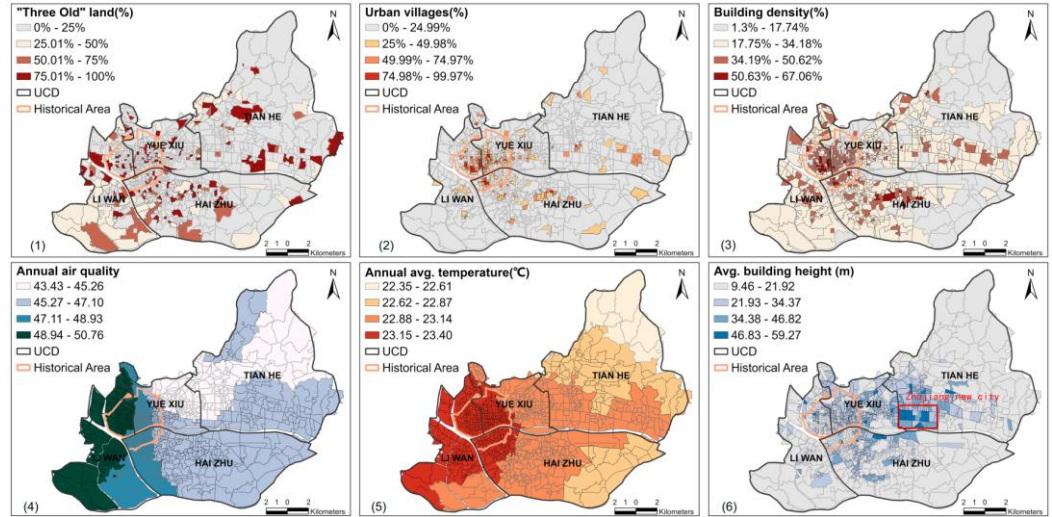


Source: own elaboration

The proportion of "Three Old" land does not exhibit a strong overall correlation with any other characteristic (Figure 7) due to the diversity of "Three Old" land composition, which includes residential, commercial, and industrial land and is dispersed in the central area. Therefore, no significant spatial clustering pattern is observed (9-1). In contrast, the proportion of urban village land (Figure 9-2) shows a strong correlation with the density of buildings (Figure 9-3) and the proportion of pre-1980 construction land, indicating that urban villages are concentrated in areas with lower buildings—consistent with the previously known low- to mid-rise, self-built housing.

In terms of environmental quality, the average air quality (Figure 9-4) and annual average temperature (Figure 9-5) show a notable correlation with the historical urban area and early developed land. These older districts, typically developed without modern planning regulations, are often characterized by narrow road networks, limited ventilation, and insufficient green space, all of which contribute to poorer air quality and elevated ambient temperatures. The findings underscore the environmental vulnerability of early-developed neighborhoods and reinforce the importance of integrating ecological improvement strategies—such as greening and climate adaptation—into urban renewal planning for these areas.

Figure 9 Distribution of “three old” land uses, building and ecological environment quality



Source: own elaboration

Regarding the renewal value, communities with higher metro coverage (Figure 10-1) show a positive correlation with population density and second-hand housing prices, highlighting the value of accessibility. The second-hand housing price (Figure 10-2) is positively correlated with the building height (Figure 9-6), suggesting that the height serves as a proxy for building age and housing quality. In other words, newer dwellings tend to be constructed higher. Since the 1990s, Guangzhou has constructed 94 high-rise condominiums exceeding 100 meters (Qiu, 2024), which were mainly located in the Zhujiang New City area, Tianhe District (Figure 9-6).

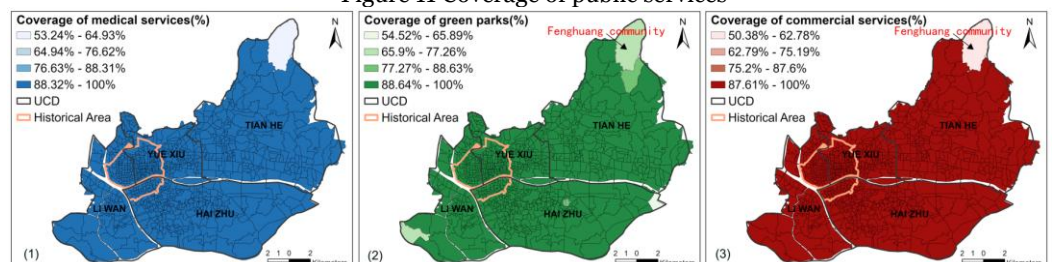
Figure 10 Community renewal value



Source: own elaboration

The coverage rate of public facilities, including medical, commercial, and green spaces, shows the lowest correlation with other indicators. This is because the four central districts of Guangzhou already have well-developed public service infrastructure (Figure 11). Except for the Fenghuang community in the upper-right corner, the 1,500-meter service coverage radius for all types of facilities is close to 100%. The coverage in the Fenghuang community is relatively lower because this study adopts a buffer-analysis based on facility center points, whereas more than 70% of the community is reservoirs or forest parks.

Figure 11 Coverage of public services



Source: own elaboration

In summary, apart from public services, the remaining indicators exhibit a high spatial heterogeneity in Guangzhou's central urban area, making a comprehensive renewal potential assessment at the city-wide level particularly necessary. This preliminary analysis suggests that public facilities are no longer the primary driver of urban renewal potential for Guangzhou. Instead, the renewal of old buildings, the reallocation of land resources and the environmental enhancement have become primary tasks driving current urban renewal efforts.

4.2. Comparative analysis of urban redevelopment potential results

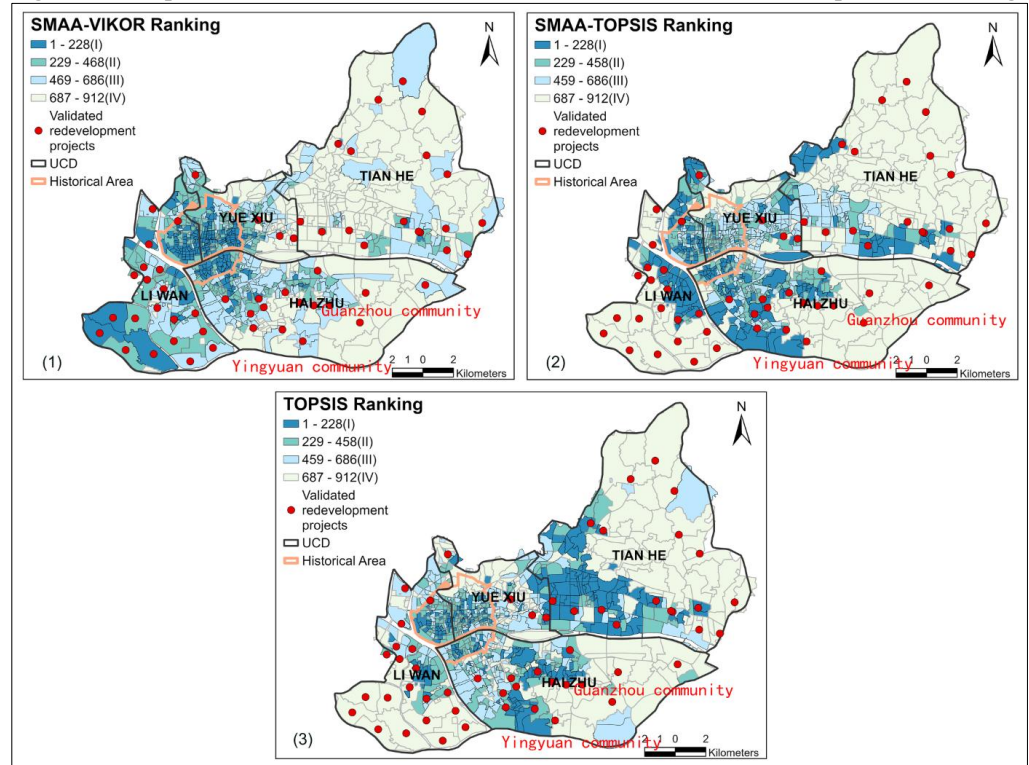
To facilitate comparison, renewal potential rankings are grouped into quartiles (Table 3) and classified, from highest to lowest, as High (I), Relatively High (II), Medium (III), and Low (IV). Overall, SMAA-VIKOR shows superior alignment with observed project locations compared with SMAA-TOPSIS and TOPSIS. Specifically, 51 project sites (nearly 83%) fall within communities ranked in categories I–III under SMAA-VIKOR. In contrast, roughly half of the projects are assigned to the lowest quartile (IV) by SMAA-TOPSIS and TOPSIS, even though these two methods identify more project sites in the top quartile than SMAA-VIKOR. It indicates that SMAA-VIKOR better synthesizes multiple criteria and yields a more robust prioritization, particularly in communities with similar characteristics. Moreover, relative to VIKOR, two TOPSIS methods assign a larger share of observed projects to the highest and lowest quartile. This implies that TOPSIS could produce a more polarized ranking under certain weighting schemes, as it defines performance by closeness to the ideal solution (and remoteness from the anti-ideal). It may magnify differences between communities with markedly different profiles.

Table 4 Comparison of redevelopment project locations and renewal potential results

Model	Distribution of projects								Redevelopment projects
	I (1-228)		II (229-456)		III (457-685)		IV (686-912)		
SMAA- VIKOR	9	14.75%	18	29.51%	24	39.34%	10	16.39%	61
SMAA- TOPSI S	15	24.59%	8	13.11%	6	9.84%	32	52.46%	61
TOPSI S	16	26.23%	12	19.67%	3	4.92%	30	49.18%	61

Source: own elaboration

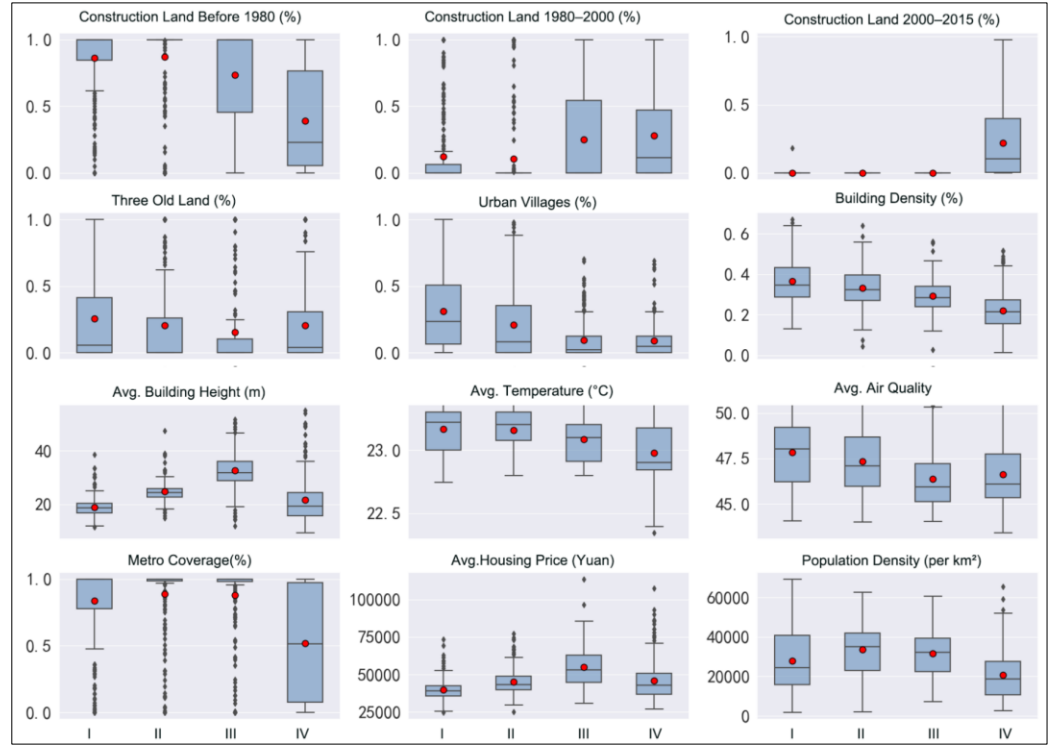
Figure 12 Comparison of SMAA-VIKOR, SMAA-TOPSIS and TOPSIS renewal potential rankings



Source: own elaboration

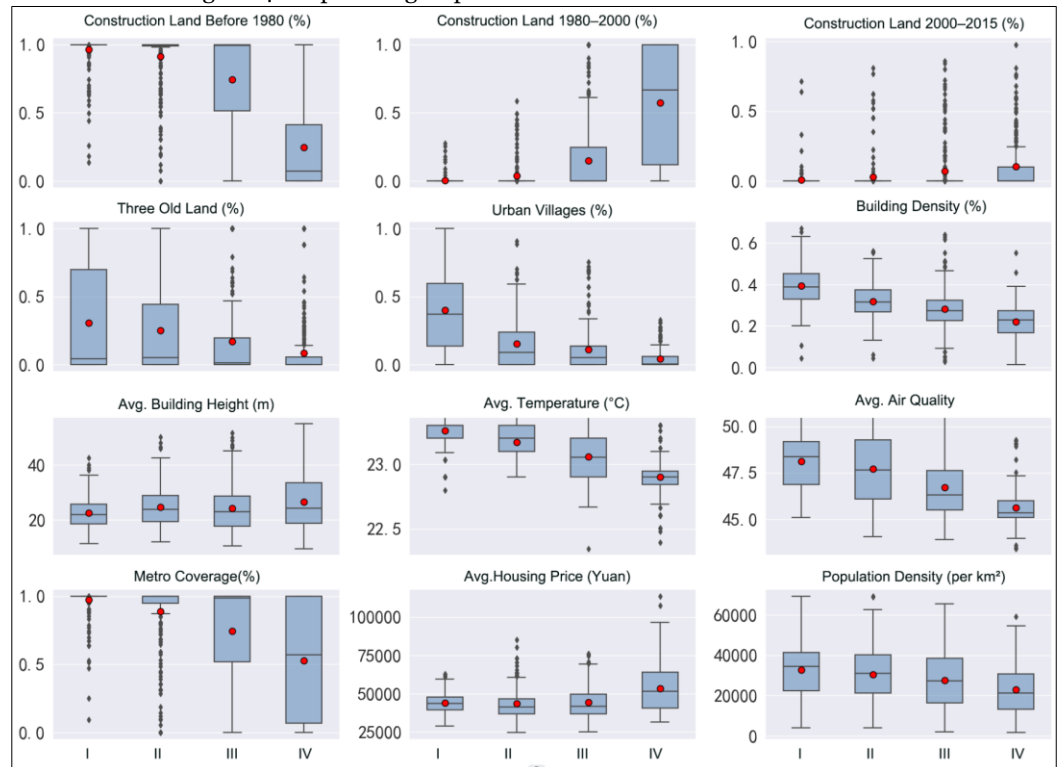
Secondly, although SMAA-TOPSIS and TOPSIS yield broadly comparable results in terms of the number of communities in each potential level, their spatial patterns differ markedly (Figure 12). Under TOPSIS, many communities classified as high potential are clustered to the north of Zhujiang New Town—areas that were largely developed after 2000 (Figure 12-3). This bias is largely attributable to TOPSIS’s reliance on fixed entropy weights, which mechanically up-weights indicators with greater cross-community variance regardless of whether they are substantively important for renewal decision-making. By contrast, SMAA-TOPSIS mitigates this issue through stochastic weight sampling: communities in the same area experience notable rank declines, suggesting that the “high potential” designation is not robust once plausible weight uncertainty is introduced.

Figure13 Boxplots of group characteristics based on SMAA-TOPSIS



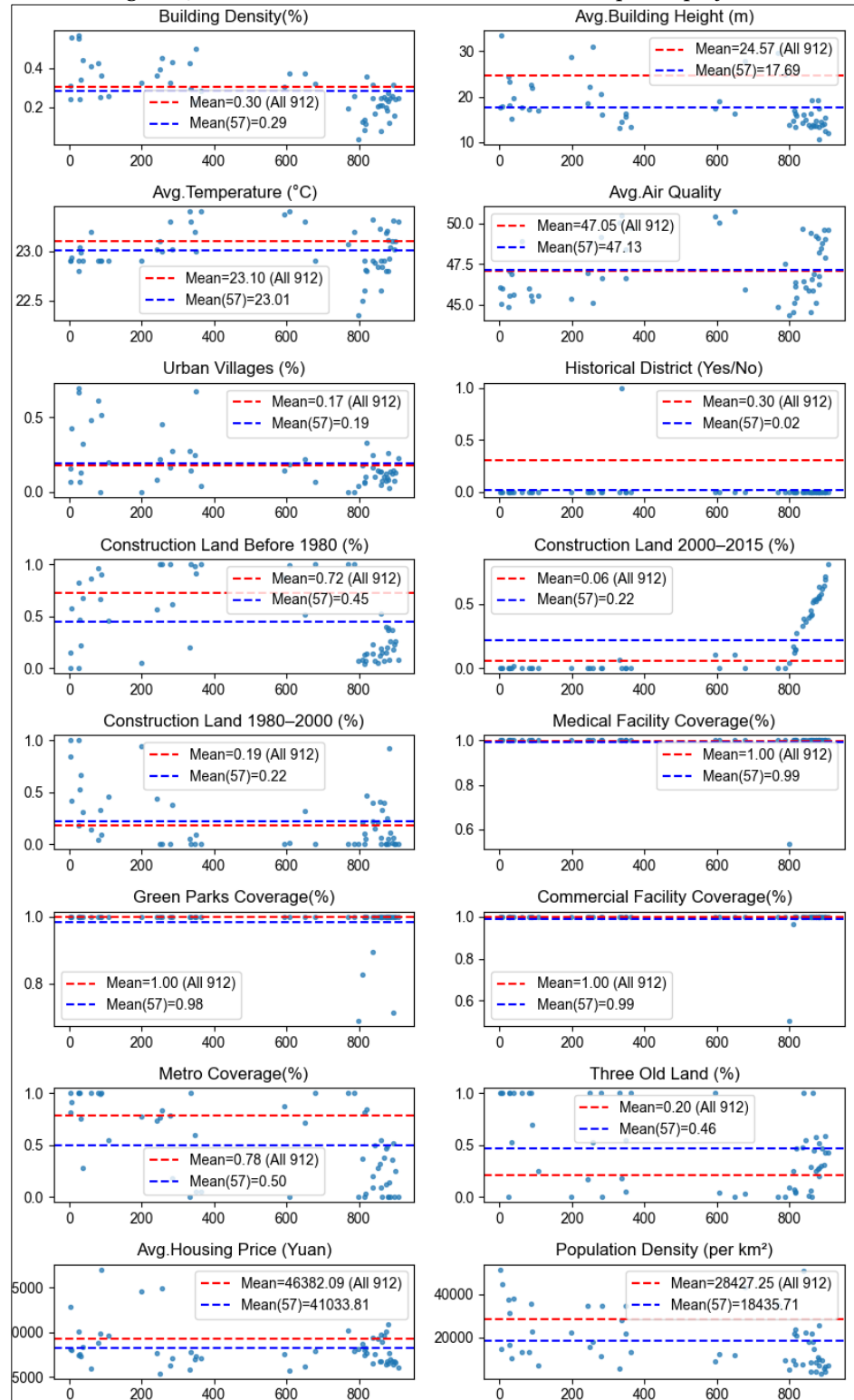
Source: own elaboration. Note: the red dot is the mean value of the group.

Figure14 Boxplots of group characteristics based on SMAA-VIKOR



Source: own elaboration

Figure 15 The statistics of communities with redevelopment projects



Source: own elaboration

In terms of characteristics among different groups of communities, both SMAA-TOPSIS (Figure13) and SMAA-VIKOR(Figure14) highlight similar attributes: the development periods, proportion of "Three Old" lands, building density and heights, economic viability, and metro accessibility. Communities with high renewal potential are mainly those with a high percentage of "Three Old" areas and urban villages. However, compared to SMAA-TOPSIS, SMAA-VIKOR produces a more reasonable categorization that reflects balanced trade-offs between criteria. For example, SMAA-TOPSIS places notably higher average building heights distinctly in categories III. By contrast, SMAA-VIKOR's categorization is smoother, with building heights gradually increasing as renewal potential decreases. In terms of "Three Old" lands, SMAA-VIKOR displays clearer gradients and differentiation among categories, while SMAA-TOPSIS shows a convex shape between Categories I and IV.

For further investigating the effectiveness of the classification, Figure 15 compares communities with redevelopment projects and all communities in terms of the mean value of indicators. The red dashed line is the mean value of attributes of all 912 communities, while the blue dashed line is the mean of those 57 communities only. Scatters are the corresponding values of 57 communities. Each chart plots one attribute on the y-axis, with the x-axis being the community index of the 57 communities. These communities were mainly developed before 2000. Compared to the total average, they have a higher proportion of “Three Old” land (46%), accompanied by lower average building heights (17.69 m vs. 24.57 m) and lower metro station coverage (50% vs. 78%). The 57 communities exhibit markedly lower metro coverage rates, second-hand housing prices, and population densities, suggesting that the redevelopment cost is less expensive compared to the rest places. Collectively, it suggests that the prioritized renewal places are less development density, less costly, as well as with significant incentive for urban renewal and redevelopment activities.

Combined with the previous results of SMAA-VIKOR and SMAA-TOPSIS, we can conclude that SMAA-VIKOR performs better in identifying urban renewal potential. In the classification of SMAA-VIKOR, High (I) and Relatively High (II) renewal potential communities are characterized by early development, high land use intensity, and location advantages. The renewal needs in these communities focus on alleviating population density, improving environmental conditions, and organically revitalizing historical and cultural assets. Medium (III) renewal potential communities exhibit moderate levels across all indicators. As they are located outside historic districts, have relatively lower housing prices, and contain available redevelopment land, they offer greater feasibility for large-scale redevelopment projects.

5. Conclusion and discussion

This study presents a comparative analysis of urban redevelopment potential in Guangzhou’s central urban area using advanced multi-criteria decision-making methods: SMAA-VIKOR and SMAA-TOPSIS, both incorporating stochastic weight simulations. Leveraging a multi-dimensional system of indicators—including renewal demands, renewal value and the cost, the research captures the complex trade-offs embedded in renewal prioritization, as well as offers insights into how different MCDM approaches interpret these complexities.

Methodologically, SMAA-based models offer a clear advantage by explicitly addressing the uncertainty and subjectivity of weight assignment in MCDM—an issue that is particularly salient in urban planning, where multiple and often conflicting criteria should be considered. By randomizing the weight space, SMAA produces not only rankings but also robustness and acceptability information, making the results more transparent and interpretable as probabilistic priorities rather than single-point conclusions. This is crucial for informing renewal policies, since it helps reduce “seemingly reasonable but non-robust” identifications that may arise under fixed-weight methods.

Regarding the result of comparison, SMAA-TOPSIS and SMAA-VIKOR show some degree of convergence in identifying high-potential urban areas. However, SMAA-VIKOR demonstrates a more balanced and nuanced ranking of community renewal potential by clearer trade-offs among indicators. 83% of which fall into the high or medium potential categories under SMAA-VIKOR, compared to just under 50% under SMAA-TOPSIS. These results indicate that the proposed stochastic-weight, compromise-ranking framework not only corroborates previous understandings of renewal indicators but also enhances the applicability of urban renewal potential assessment to help the decision-making. A compromise-ranking logic can better reflect the actual decision process of urban renewal where rarely follow a “worst-first” or “best-first” rule but instead depend on trade-offs among need, value, and feasibility.

From a practical perspective, in China, the current urban renewal policy adopts a “diagnosis-before-renewal” approach. However, this process still focuses primarily on identifying individual problems and provides limited guidance for overall renewal planning and evaluation. The proposed method in this study can therefore offer valuable support for large-scale assessment of renewal potential and for informing planning adjustments. Although we fail to compare other types of renewal projects, such as mixed or micro-renewal projects with the SMAA-VIKOR result due to the data accessibility, 70% of the redeveloped projects that are located in II and III segment of SMAA-VIKOR ranking indicates that it is possible to distinguish different potentials for different types of projects. This could support more targeted renewal strategies: communities with high renewal demands—often characterized by early development periods, dense but lower-rise forms (e.g., “Three Old” land and urban villages), and strong accessibility advantages—may be prioritized for organic regeneration and environmental enhancement, whereas medium-potential areas, usually outside the historic center, may provide room for more extensive redevelopment and functional restructuring.

At the same time, due to data availability, this study does not fully consider the governance feasibility such as detailed renewal policies and community acceptance, which play critical roles in actual renewal implementation. Future studies can extend the SMAA framework by integrating such constraints—along with implementation capacity and policy readiness—so that large-scale renewal potential assessment evolves into a more comprehensive decision-support tool for planners.

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7. Credit Author Statement

LY: research design, methodology, data analysis, writing and revision; HZ: conceptualization, funding acquisition; MZ: supervision; HX: data collection and processing.

Conflict interests: The authors declare that they have no conflicts of interest.

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