Hindawi
Journal of Mathematics
Volume 2023, Article ID 3251188, 18 pages
https://doi.org/10.1155/2023/3251188

Research Article

Evaluation on Site Selection of Urban Renewal Projects from the Perspective of Space Benefit: Macau Special Administrative Region as an Example

Zehui Chen,[1,2,3] Yalong Xing,[3] Guang Huang,[1,2,3] and JingXian Li[3]

[1]*Sino-Portugal Belt and Road Joint Laboratory on Science of Cultural Heritage Conservation, City University of Macau, Macau 999078, China*
[2]*Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, Guangdong 519000, China*
[3]*Faculty of Innovation and Design, City University of Macau, Macau 999078, China*

Correspondence should be addressed to Guang Huang; ghuang@cityu.mo

Received 2 August 2022; Revised 22 February 2023; Accepted 16 March 2023; Published 17 April 2023

Academic Editor: Ghous Ali

With the advent of the stock-planning era, urban renewal has gradually become an important part of urban construction. Urban renewal is essentially a process of solving the rational redistribution of space. However, blind urban renewal can easily lead to the waste of space resources. Therefore, an appropriate renewal location can maximize the space's renewal efficiency. Based on the perspective of space benefits, this study constructs an urban renewal site selection evaluation system suitable for Macau SAR from two aspects of social and economic benefits and space benefits and uses the DEA model to verify the evaluation system. Thus, we can more objectively and directly judge the evaluation of benefits in urban renewal site selection, maximize the efficiency of spatial renewal, and provide reference for urban site selection decisions. The results are as follows: Funing Building is the best item among the four renewal projects, and it is also the most suitable target point for development; the super-rich benefit is inefficient in terms of both space benefit and production cost benefit.

1. Introduction

After 20 years of rapid development since the handover, the Macau region is gradually facing problems, such as traffic congestion, an ageing population, and deteriorating environmental quality. Urban renewal is considered an effective strategy to solve urban aging and to realize urban economic, environmental, and social goals. At the same time, as my country is gradually entering the urban renewal stage of "stock optimization," it will gradually get rid of the previous modes of "scale expansion" and "large-scale demolition and construction," so as to improve the development connotation and spatial quality through urban renewal. Urban renewal is the process of reusing resources and rebuilding the urban environment, which has the potential to contribute to sustainable development if it follows a sustainable approach. However, due to the lack of evaluation and demonstration of site selection in the practice of urban renewal projects, a lot of resources have been wasted.

Macau's urban redevelopment first originated from the "Consultation Committee on Restructuring of Old Areas" ("Legal System for Restructuring of Old Areas") in 2005. In 2016, the "Urban Renewal Committee" (Administrative Regulation No. 5/2016) was established to replace the Restructuring of Old Areas. It was not until 2019 that a government-led "Urban Renewal Co., Ltd. (Administrative Regulation No. 12/2019) was established more than 15 years ago. At the same time, the city of Macau is rapidly ageing; many buildings are on the verge of becoming dangerous; threats to the personal safety of citizens and the deterioration of the urban environment urgently require the organic renewal of the city. Urban renewal in Macau has been slow. It has taken many years to establish urban renewal laws and institutions, and it is even more difficult to implement urban renewal projects. In addition, there is a lack of objective evaluation methods for urban spatial transformation project investment, and developers cannot effectively judge whether the outcome of urban renewal project selection is conducive to rational resource allocation and benefit maximization. The uncertainty of spatial and economic input-output risks often hinders the progress of urban renewal projects. Therefore, this study attempts to analyze the urban renewal performance of the Macau region based on the perspective of spatial benefits and the DEA model, which effectively reflects the relationship between social, economic, and environmental aspects of urban renewal projects in terms of space and emphasizes the assessment of the cost-benefit of project implementation in terms of inputs and outputs without dimensionless processing and weight assignment treatment, so as to achieve the maximum rational allocation of spatial resources. It also further validates the objectivity and efficiency of the DEA model as an assessment of the benefits of urban renewal site selection by using the comprehensive evaluation method as a comparison. It provides ideas and references for solving the existing problems of allocating the benefits of urban renewal in Macau.

2. Research Overview

2.1. Urban Renewal Performance. Urban renewal began earlier in Europe and the United States. For example, the American housing economist Miles Colean proposed the concept of urban renewal in 1953. He believed that urban renewal should restore the vitality of the city and promote the efficient use of urban land. Most of his early development models used "bulldozers" to demolish the old and build the new ones [1], but this caused many problems, such as increased costs and the psychological burden of the demolished. Many scholars have also begun to introduce the concept of sustainable development. Upgrading should take into account public opinion and upgrade organically in a step-by-step manner. Fairbanks [2] believes that urban renewal aims to continuously improve the socio-economic and environmental conditions of the areas to be developed and to solve urban problems in a comprehensive and coordinated manner. Urban renewal should accept public opinion and update organically in a gradual way. Therefore, people-oriented sustainable development has also led to the evaluation of the benefits of urban renewal, but, at present, there are relatively few studies by scholars on the benefits of urban renewal. Schofield [3] was the first to apply cost-benefit analysis (CBA) to economic evaluation in urban planning, including urban regeneration projects. Chan and Lee [4] argue that if we overemphasize economic goals, it will not be conducive to promote the global trend of sustainable urban development and the environmental and social benefits from community conditions. Shen et al. [5] summarised urban sustainability indicators proposed by several institutional organizations and researchers to reflect sustainable urban development in four dimensions: social, economic, environmental, and governance. La Rosa et al. [6] proposed a method to spatially quantify the benefits of regenerating areas by combining environmental and urban factors, such as reduced seismic risk, increased accessibility, and land use diversity. Manupati et al. [7] identified seven aspects and 27 subcriteria related to economic, social and environmental aspects from the literature on socio-technical perspectives and demonstrated their validity using the South Indian Urban Renewal Project. Cabanek et al. [8] have integrated probiotic streets through a pronaturalist lens into the spatial design of four street revitalization projects in Victoria–Gasteiz, Berkeley, Portland, and Melbourne, stimulating economic, social, and environmental benefits of renewal. Pérez et al. [9] construct a sustainability assessment of urban regeneration in terms of six community-scale development goals, including economic and environmental, to take into account the specificity of existing buildings, businesses, and residents in the Swiss community of "Moulins". In China, in the 1980s, Chen Zhanyuan defined urban renewal as the process of "urban metabolism," Wu Liangyong placed more emphasis on urban "organic renewal." Chen and Zhou [10] argue that urban renewal is about restructuring the social structure of old urban areas, replacing facilities, improving the environment, and evacuating traffic to reconfigure the physical space of buildings, and points out that urban renewal should uphold the principle of sustainable development, consider economic, environmental, and social benefits and strive to maximize comprehensive benefits. Assessing the transformational benefits of projects is at the heart of urban regeneration. Based on the new connotation of urban renewal, Li [11] argues that urban renewal should be considered more from the perspective of a stakeholder game based on the replacement of physical space and identifies 30 impact factors to explore the comprehensive benefits of urban renewal with social, economic, and environmental benefits as modules. Based on "spatial performance," Cao et al. [12] established an evaluation system with three main components, spatial effectiveness, spatial efficiency, and spatial equity, and used hierarchical analysis to validate the system using Hangzhou as an example.

2.2. Performance Evaluation Model. In evaluating urban renewal performance, most scholars use quantitative methods such as hierarchical analysis [13], TOPSIS [14], the fuzzy evaluation method [15], and a hybrid genetic algorithm [16], but these methods only consider the output benefits in urban renewal performance, while ignoring the multiobjective and dynamic nature of outputs of urban renewal. In fact, urban renewal performance is consistent with the idea of input-output efficiency in economics [17]. In recent years, the "input-output" mode of thinking in Data Envelopment Analysis (DEA) has become increasingly popular among scholars, and DEA is now widely used in economics [18], environmental science [19], finance [20], etc. Arsu [21] investigated the sporting ability and revenue of clubs using the biobjective multicriteria data envelopment analysis (BiO-MCDEA) model and also verified the significant correlation between the indicators of inputs and outputs in DEA. Rasoulzadeh et al. [22] proposed a new portfolio Markowitz and cross DEA model to achieve the optimal portfolio by accepting the minimum risk. Zou et al. [23] took the Longmencheng site and the Ming Dynasty King's Tomb in Wuhan as examples and invented a multidimensional evaluation method based on the GIS-DEA-Ml model to compare the dynamics of spatial development efficiency and nonspatial development efficiency of the two cultural landscape heritage cases mentioned above. The DEA approach can also be applied to site selection for urban renewal benefits. Huang et al. [24] categorised urban renewal projects in Taipei into three dimensions of environmental, economic, and social, by classifying them into decision units, and evaluated the efficiency of renewal projects based on DEA. Tang et al. [25] combined energy analysis and SBM-DEA to construct an eco-efficiency model and illustrated the applicability of this eco-model in urban regeneration using the questionnaire statistics of Chongqing, China, as an example. Numerous studies have shown that DEA treats the study area as a grey system in a complex urban system, focusing on the relationship between its "input" and "output," instead of studying the interaction of various factors, similar to "black box operation," which can avoid the bias caused by the interaction of the internal links of the complex urban system and thus obtain more realistic performance evaluation results.

Scholars have conducted a wealth of research on the benefits of urban regeneration, but in general, there are the following characteristics: first, most studies have focused on the evaluation of the traditional three-dimensional system. That is, using the social, economic, and environmental dimensions to analyze the sustainability of urban renewal, the methodology used to spatially evaluate the benefits of urban renewal remains a less addressed area of research in urban planning studies. Second, the DEA model is based on the premise of multi-indicator data measurement, and its main advantage is that it does not require dimensionless processing and indicator weight determination, and it also does not need to set the specific form of the frontier production function. Most of the other evaluation methods need to assign weight values directly or indirectly by humans, so the evaluation results can maximize the reduction of bias due to subjective factors. At present, few scholars analyze spatial efficiency and DEA models together to evaluate the benefits of urban renewal, so this paper attempts to combine the two and conduct an empirical study on the location of urban renewal priority transformation projects in Macau SAR, which can provide a practical case study for evaluating the dynamic benefits of urban renewal, and then help to implement scientific and reasonable spatial control of regional land resources to promote intensive and economic use of land.

3. Research Ideas

3.1. Research Content. This research adopts the multifactor analysis method to construct the "target-criteria-indicator" evaluation system and uses the spatial indicators calculated by the geographic information system to demonstrate and evaluate several urban renewal projects in the Macau special administrative region and to propose corresponding management suggestions for this purpose, as shown in Figure 1.

3.2. Construction of an Indicator System. Based on the indicator system of HaiFeng Liang, YiMin Cao, Kuan-Hua, and Daniele, as well as the principles of geographical differences, quantitative integration, and operability, this paper selects four aspects of the urban renewal projects, namely, spatial accessibility, spatial diversity, spatial risk, and economic and social benefits as the index system of transformation potential, as shown in Table 1.

3.3. Evaluation Methods of Urban Renewal Projects

3.3.1. Entropy Method. In multi-index decision problems, the weight of each index needs to be determined, which requires an evaluation of the effectiveness and utility of the information obtained. To determine the weights of indicators, subjective weighting methods, such as AHP, are usually used, which often leads to biases in the evaluation results due to human subjective factors. Therefore, this paper adopts the entropy method as an objective weighting method to determine the weights of indicators at all levels. Entropy is a measure of the degree of disorder in a system, and it can measure the amount of effective information provided by the data. When the value of the evaluation object is very different for a certain index, the entropy value is small, indicating that the effective information provided by the index is larger and the weight of the index is correspondingly larger, and vice versa [14, 26].

(1) Data Standardization. Considering that different indicators have different dimensions and values, the traditional method of range standardization is used to solve the effects of different indicators and dimensions due to the inability to aggregate. Range standardization refers to the method of standardizing the positive and negative indicators of the original data and finally achieving the process of normalizing the data of different indicator values to the [0, 1] interval. The specific operation formula is as follows.

If the evaluation index X_j is a positive index or a negative index, then

$$\begin{aligned}\text{Positive indicator: } X_{ij}{}^{*} &= \frac{Xij - \min\left\{X_{\mathrm{j}}\right\}}{\max\left\{X_{\mathrm{j}}\right\} - \min\left\{X_{\mathrm{j}}\right\}},\\ \text{Negative indicator: } X_{ij}{}^{*} &= \frac{\max\left\{X_{\mathrm{j}}\right\} - Xij}{\max\left\{X_{\mathrm{j}}\right\} - \min\left\{X_{\mathrm{j}}\right\}}.\end{aligned} \tag{1}$$

(2) Calculate the Weight. We calculate the proportion of the i-th city/year to this indicator under the j-th indicator P_{ij}:

$$P_{ij} = \frac{X_{ij}^{*}}{\sum_{i=1}^{n} X_{ij}^{*}}. \tag{2}$$

We calculate the entropy value e_j of the j-th index:

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} P_{ij}\ln P_{ij}\left(\mathrm{e_j} \geq 0\right). \tag{3}$$

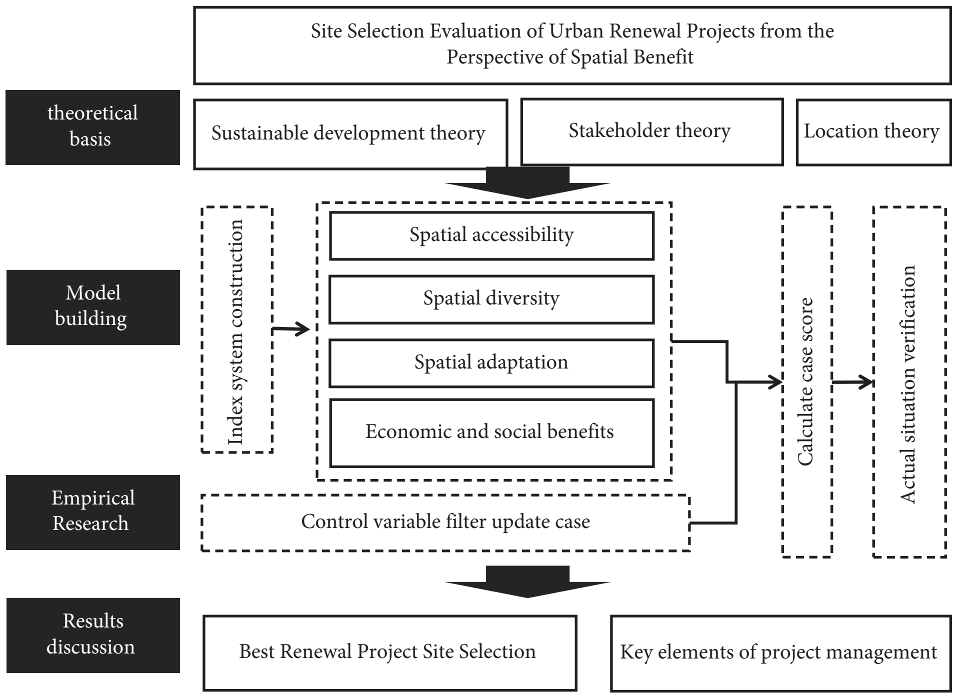

Figure 1: The technical route of urban renewal site selection assessment (source: self-drawn by the author).

We calculate the difference coefficient d_j of the j-th index:

$$d_j = 1 - e_j. \quad (4)$$

We calculate the weight w_j of the j-th indicator:

$$w_j = \frac{d_i}{\sum_{j=1}^{m} d_i} \, (j = 1, 2, \cdots, m). \quad (5)$$

3.3.2. Multifactor Comprehensive Evaluation Method. When evaluating the benefits of urban renewal, scholars mainly use these evaluation models: fuzzy comprehensive evaluation, systematic clustering, principal component analysis, and multifactor comprehensive evaluation. Due to the different evaluation objects and evaluation purposes, the selected evaluation models are also different. Combined with the actual situation, this paper adopts the multifactor comprehensive evaluation method with less subjective influence on the evaluation results to evaluate the renovation potential of the Shunde urban renewal project in Shunde. The formula expression is as follows:

$$S = \sum_{j=1}^{n} W_j P_{ij} (j = 1, 2, \ldots, n). \quad (6)$$

3.4. Data Envelope Analysis. The data envelopment analysis model was developed by A. Charnes, W.W. Cooper, and E. Rhodes in 1978 and has been widely used in the field of project and policy evaluation. It uses a mathematical programming model to evaluate the relative effectiveness (DEA effectiveness) of "departments" or "units" (called decision-making units or DMUs) with multiple inputs, especially multiple outputs [27].

The model is divided into C^2R and BC^2 according to "whether the return to scale is variable or not." Most of the existing studies are based on the C^2R model to discuss the performance or site selection evaluation of urban renewal, that is, to judge that urban renewal is not only technically effective but also scale efficient. Therefore, this paper also uses the C^2R method to quantitatively compare the input and output data of the urban renewal site selection evaluation. In this way, the rationality of spatial performance site selection is tested, and the formula is obtained by referring to the relevant literature as follows [28, 29]:

There are n decision-making units $DMU_j (1 \leq j \leq n)$, and each DMU_j has m input items $(i = 1, 2, 3, \ldots, m)$ and s output items $(r = 1, 2, 3, \ldots, s)$ obtain.

Input variable: $X_j = (x_{1j}, x_{2j}, x_{3j}, \ldots, x_{mj})$; output variable: $Y_j = (y_{1j}, y_{2j}, y_{3j}, \ldots, y_{sj})$.

Assuming that the weight coefficient of the input of the i-th item is v_i and the weight coefficient of the output of the r-th item is u_r, the efficiency evaluation index can be obtained as follows:

$$Z_j = \frac{u_r Y_j}{v_i X_j} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \, (j = 1, \cdots, n). \quad (7)$$

In order to maximize Z_j, $Z_j \leq 1$, we form the fractional programming model (C^2R) of DEA:

Table 1: Evaluation indicators of urban renewal project site selection from the perspective of spatial benefit.

Target layer	Criterion layer	Indicator layer	Indicator meaning	Nature	Source
Update site selection assessment	Economic and social benefits	X_1: space income created by capital	Reflect the investment cost of the renewal project	+	Building area after renewal/building renewal investment
		X_2: space benefits created by time	Reflect update project time cost	+	Building area after renewal/update time
		X_3: percentage of ownership consent	Reflects the distribution of recognition among stakeholders	+	Visit statistics
	Spatial adaptation	X_4: storm surge impact	Reflect the impact of disasters on renewal projects	−	Macau meteorological and geophysical bureau
		X_5: air quality	Reflect the impact of the environment on the renewal project	+	Macau meteorological and geophysical bureau
	Spatial accessibility	X_6: project accessibility	Reflects the potential of the project to attract people	+	Macau cadastre bureau
	Spatial diversity	X_7: land use structure entropy	Reflect the diversity of land use types	+	Macau cadastre bureau

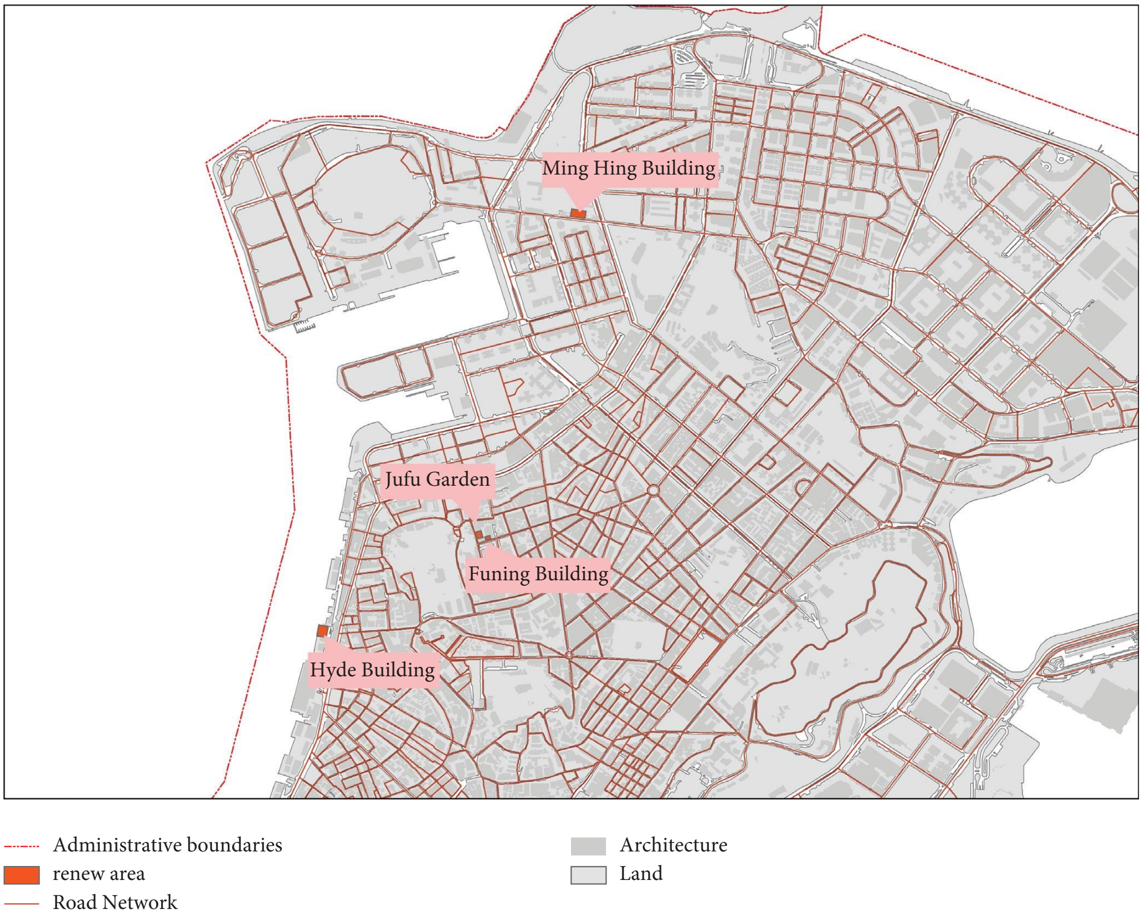

Figure 2: Overview of the study area (source: self-drawn by the author).

$$\left(C^2R\right)\begin{cases} \max Z_{j0} \\ Z_j \leq 1, j = 1, \cdots, n \\ u_r \geq 0, v_i \geq 0, u_r + v_i = 1 \end{cases}. \quad (8)$$

If $t = (1/v_i X_0)$, $\omega = tv_i$ and $\mu = tu_r$, the fractional programming problem is transformed into an equivalent linear model P:

$$\left(P_{C^2R}\right)\begin{cases} \max \mu_r Y_0 \\ \omega_i X_j - \mu_r Y_j \geq 0, j = 1, \cdots, n \\ \omega_i X_0 = 1 \\ \omega_i \geq 0, \mu_r \geq 0 \end{cases}. \quad (9)$$

Finally, we take the dual model D of the planning model P:

$$\left(D_{C^2R}\right)\begin{cases} \min \theta \\ \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} X_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, j = 1, \cdots, n \\ S^- \geq 0, S^+ \geq 0 \end{cases}. \quad (10)$$

Among them, $S^- = (S_1^-, S_2^-, \ldots, S_m^-)$ is the slack variable of m input; $S^+ = (S_1^+, S_2^+, \ldots, Ss^+)$ is the slack variable of s output; $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n)$ is the n decision-making unit DMU combination coefficient.

Let λ_0, S^{-0}, S^{+0}, *and* θ_0 be the optimal solution of (D_ε); then,

(1) $\theta_0 < 1$; then, DMU_{j0} is DEA invalid, and the unit can reduce the input to the ratio of θ_0 of the original input X_0 through the combination and keep the original output Y_0 unchanged

(2) $\theta_0 = 1$, $e_1^T S^{-0} + e_2^T S^{+0} > 0$; then, DMU_{j0} is weakly DEA effective; that is, in the system composed of n decision-making units, the input X_0 can be reduced by S^- and the original output Y_0 can be kept unchanged, or the output can be increased by S^+ when the input X_0 remains unchanged

(3) $\theta_0 = 1$, $e_1^T S^{-0} + e_2^T S^{+0} = 0$; then, DMU_{j0} is valid for DEA; that is, the output Y_0 obtained by this unit on the basis of the original input X_0 has reached the optimum

(4) Let $K = \sum_{j=1}^{n} \lambda_j * (1/\theta)$; when $K = 1$, the DMU is said to be efficient in scale; when $K < 1$, the scale returns are increasing; when $K > 1$, the scale returns are decreasing

Table 2: Macau urban renewal methods.

Leading	Folk-led		Government-led
Organize	Homeowners' association and neighborhood federation		Urban renewal council
Sources of funds	Crowdfunding	Company investment	"Company + government + residents" joint investment
Represent	Ming Hing Building, Ju Fu Garden	New Funing, Hyde Building	Youhan seventh floor group
Features	Easy ownership, obvious benefits, and small scale		Complex ownership, insufficient funds, and large scale
State	Finish	Finish	Processing

Source: made by the author.

Table 3: Macau Urban Renewal Socioeconomic Data.

Criterion layer	Indicator layer	Funing Building	Hyde Building	Ming Hing Building	Ju Fu Garden
Economic and social investment	Construction renewal investment (10,000 mop)	1120	1900	1225	1080
	Proportion of owners agreeing (%)	100	85	100	100
Economic and social output	Price after renovation (per sq ft/10,000 mop)	1.63	0.95	0.72	0.53
	Retrofit time (year)	4.5	5	5	4
	Building area after renovation (m^2)	3284.47	1716.92	617.02	753.17
	Proportion of public service area	4.7844	0.0000	16.7331	3.7636
Space income created by funds (m^2)		2.9326	0.9036	0.5037	0.6974
Space revenue created by time (m^2)		729.882	343.384	123.404	188.2925

Note. The proportion of owners agreeing to the renovation is based on the first vote. Source: the official websites of the Macau Statistics and Census Bureau and the Macau Cadastral Bureau, etc.

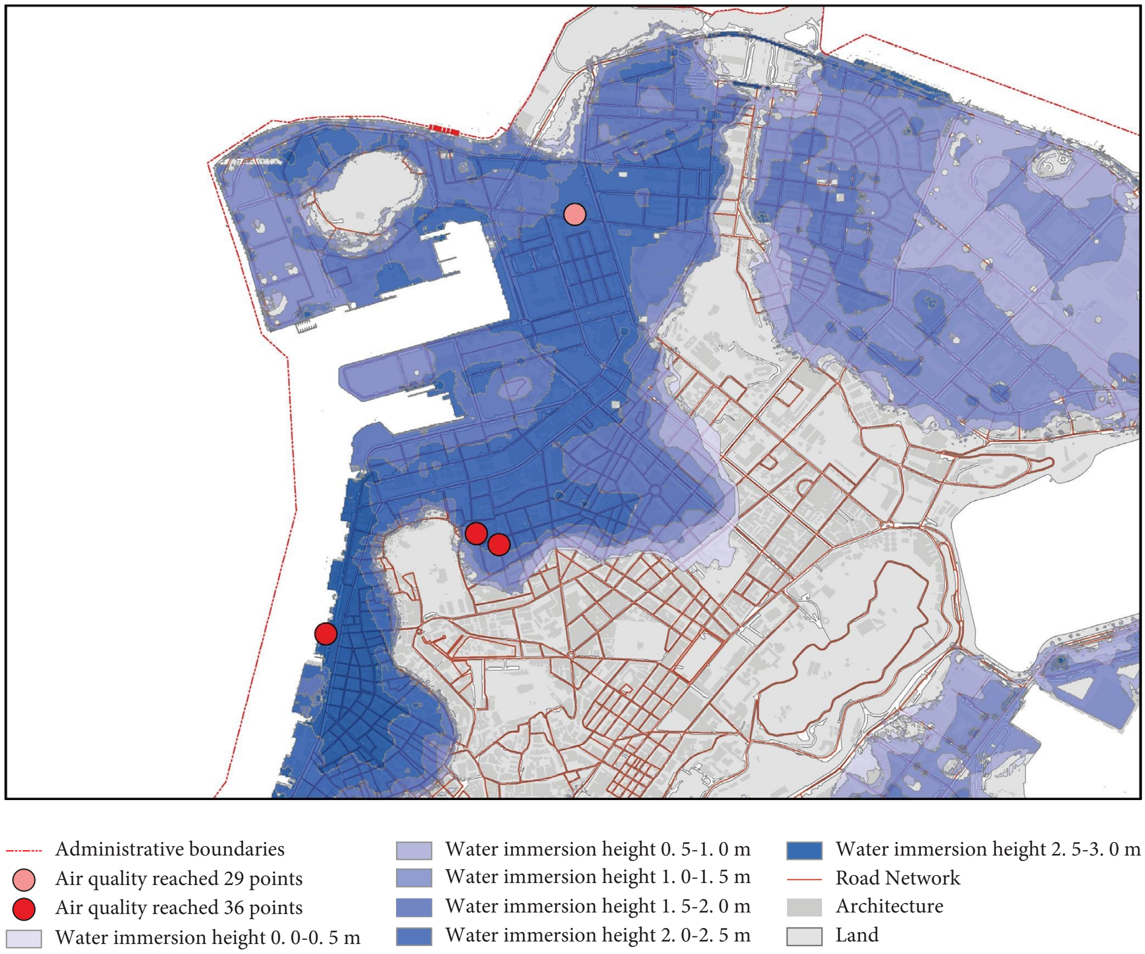

Figure 3: Assessment of Macau's urban renewal space adaptability (source: self-drawn by the author).

3.5. Data Sources. The road network and vector map data in this study were obtained from the conversion of the Macau Cadastre Bureau and Websites; the land use data were obtained from the draught "Macau Special Administrative Region Urban Master Plan (2020–2040);" the socio-economic data of population and renewal projects were obtained from the official websites of the Macau Statistics and Census Bureau, the Bureau of Land, Public Affairs and Transport, and the Macau Real Estate Website; the data on storm surge and climate and environmental quality were obtained from the Macau Geophysics and Meteorology Bureau.

4. Case Selection

Macau's urban renewal is still in its infancy, and the seven buildings of You Han are the only government-led urban renewal project, and it is currently the largest urban renewal project in the Macau area. The project is in the negotiation stage, and progress is very slow. The current urban renewal faces two main problems.

4.1. Percentage Ownership Issue. Under the current law, if the old neighborhood is to be rebuilt, demolition and reconstruction require the consent of 100% of the owners. If one household objects, the project is shelved or cancelled. If the issue of ownership is not resolved, urban renewal cannot take place. Society has many opinions on the ownership ratio, but it is generally believed that the ratio threshold should be lowered. At present, the ownership ratio has been reduced. The building age is > 40 years, and 80% of the houses can be renovated if the owners agree. In addition, there will be arbitration procedures to treat 20% of households as priority cases of emergency.

The issue of urban renewal is often discussed in the news and in public opinion, and there are often many articles criticising the slow efficiency of the redevelopment of old districts due to the problem of property ownership. However, according to the relevant laws of the current capitalist system of the Macao SAR, "private property is sacrosanct," so unlike urban renewal on the mainland, the Macao SAR government cannot enforce the enforcement of personal property in the form of collective interests. That is to say, it is necessary to coordinate the contradiction between "protecting private property and satisfying urban development."

4.2. Construction Cost Problem. If a building is to be demolished and rebuilt, the cost per square foot is about 2000–3000. If it is calculated on the basis of 500 feet, it will

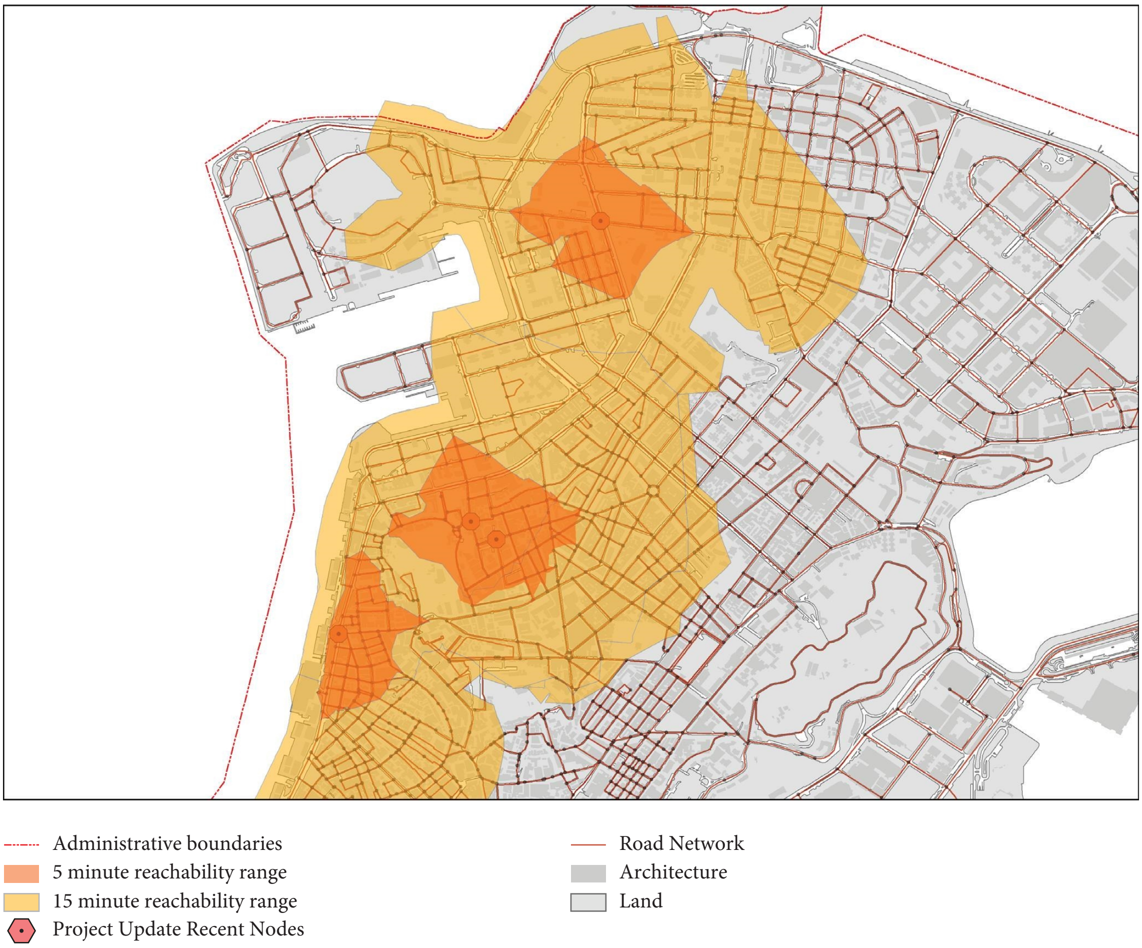

Figure 4: Assessment of the accessibility of Macau's urban renewal space (source: self-drawn by the author).

cost about 1 million. At present, it is understood that, after the establishment of the urban renewal committee, the main method is "business + government + residents." The situation of joint ventures is encouraged, and many people often cannot afford too much capital investment, so it is also particularly difficult in terms of funds. At present, many articles suggest that the reconstruction of old buildings should be updated by raising the floors, that is, increasing the floor area ratio from the perspective of citizens. People living on the original floors can move back after the renovation. In addition, the raised floors can be sold to recoup the investment before the company is rebuilt, or the locals can make their own capital contributions and even reap the benefits. Conducive to urban renewal, however, in terms of total area, Macao has a wide variety of land uses, the land is dense, the building density is high, and the distance between many buildings is very small. As a result, when floors are raised, there are often issues, such as the spacing of sunlight, fire safety, and new population support in other buildings. Therefore, it is necessary to coordinate the contradiction between "renewing economic benefits and ensuring a livable and safe life."

Therefore, due to the early start of urban renewal and the difficulty of advancing the project, the urban renewal projects that have been successfully completed in Macau at present mainly include New Funing, Hyde Building, Mingxing Building, Ju Fu Garden, and Shanfeng Garden. Their locations are shown in Figure 2. The characteristics and methods of renewal are more different from those of Youhan, mainly the reconstruction of small scale, single-building and old buildings. In order to confirm the evaluation of the site selection research studies of urban renewal projects from the perspective of space, the research of this case site is mainly based on the following successful projects (Table 2), so as to facilitate the rationality of the site selection evaluation through actual project comparison in the later stage.

5. Project Update Site Selection and System Evaluation

5.1. Social and Economic Benefits. The social and economic benefits mainly include the proportion of owners who agree to participate in urban renewal and the construction costs of urban renewal in the early stages, mainly to respond to the issue of percentage ownership in Macau and the issue of housing construction cost input. In the process of renewal, the monistic guiding idea often simplifies the process and lacks procedural justice [30], and the redevelopment of old residential areas is not only the reuse of material space but

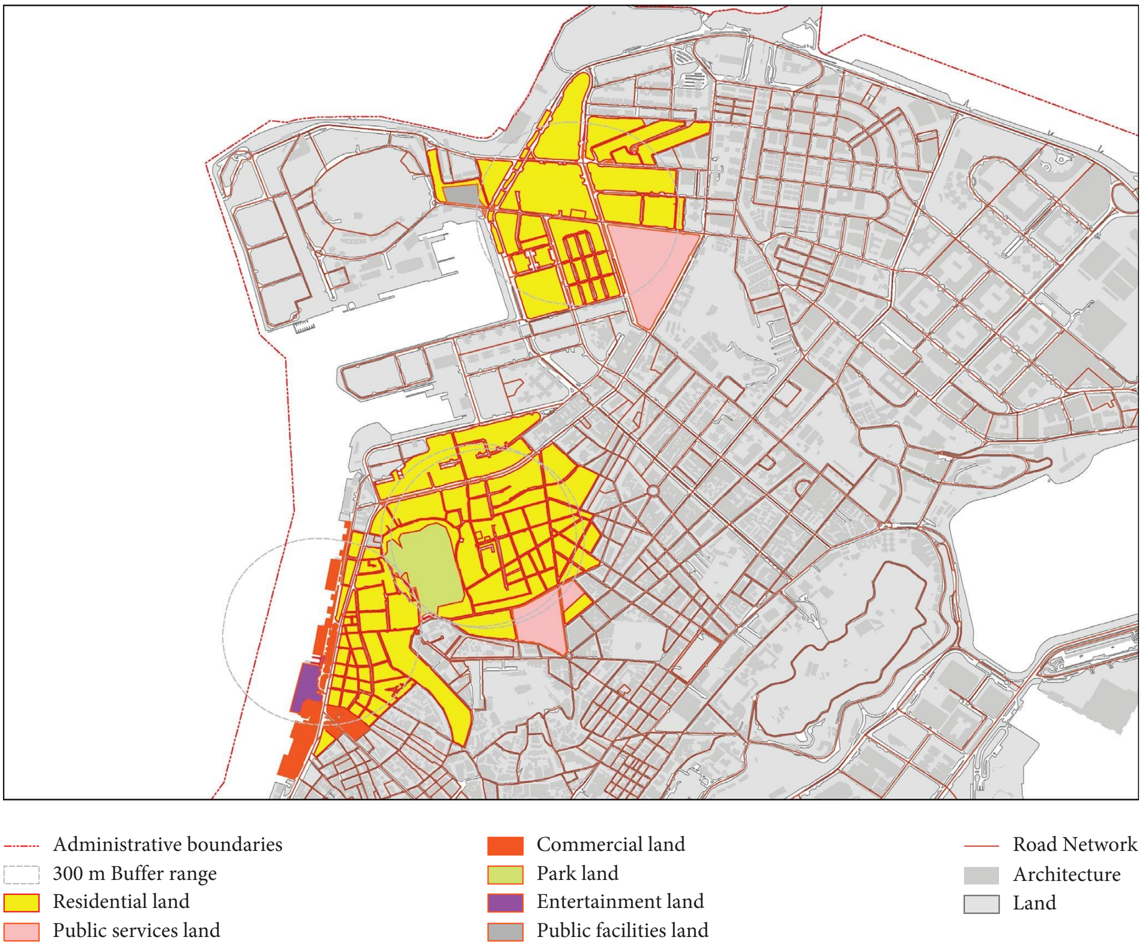

Figure 5: Assessment of the spatial diversity of urban renewal in Macau (source: self-drawn by the author).

also the process of redistribution of interests based on specific property rights. Allocation is the key to the progress of the old residential area redevelopment project [31]. The higher the proportion of owners who agree to participate in urban renewal, the smoother the implementation of urban renewal projects and the open and fair distribution of interests among owners, developers, and the government; influenced by uncertain factors, there are often huge transaction costs and become an important factor in determining whether the renewal can be promoted [32]. Construction costs are an important foundation and source of construction for urban regeneration projects, and this situation indicates that transaction costs are high when significant effort and time are required for the parties involved to reach an important agreement that is critical to the regeneration process. Therefore, the greater the investment in the construction costs, the greater the difficulty of urban regeneration [33].

Due to their similar scale, the main economic and social indicators for the four regeneration projects are not very different. It is difficult to see the difference in the proportion of owners agreeing to renew from the quantitative data. This study has learned from the relevant information from interviews and news reports that the four urban regeneration projects have one important characteristic in common: they are all driven by dilapidated buildings. Therefore, while it is related to the life and health of the owners, the willingness to participate in and agree to the regeneration project is also very active. At the same time, due to the small scale of the renewal project, the interest relationship network for different subjects in the project is relatively simple, and the subjects can quickly realize the redistribution of interests. In the benefit distribution of the renovation project, through the participation of China Merchants Real Estate Company in the renovation, an appropriate new floor is added on the basis of the original floor as a new title of the property developer's external distribution, which generates benefits for the company. The company provides the capital investment for the original residents to renovate, and the residents do not need to waste their own funds to obtain new space use rights. The redistribution of their respective spatial interests is achieved between the two, essentially on the basis of the original space, by squeezing the public space (affecting the lighting of nearby blocks) and regenerating new private space for use. This is why almost all of them have a 100% owner approval rate. Among them, the proportion of owners who agreed to the Hyde Building was initially 85% mainly because it involved the transfer of ownership and inheritance, but they quickly reached an agreement on their respective spatial interests to realize the renovation plan.

Table 4: Evaluation of Macau urban renewal site selection benefit from the perspective of spatial benefit.

	Funing Building	Hyde Building	Ming Hing Building	Ju Fu Garden	Weight
Space income created by capital (10,000 mop/m^2)	2.9326	0.9036	0.5037	0.6974	0.0739
Space revenue created by time (year/m^2)	729.8822	343.3840	123.4040	188.2925	0.0739
Proportion of owners agreeing (%)	100	85	100	100	0.0739
Storm surge impact (feet)	2.5	3	2.5	2.5	0.0883
Environmental pollution	36	36	29	36	0.1977
Project accessibility (m^2)	128854	101057	166124	158188	0.2867
Land use structure entropy	0.5041	1.06734	0.6452	0.4869	0.2055
Comprehensive evaluation value	0.5111	0.2312	0.1295	0.1287	

Source: made by the author.

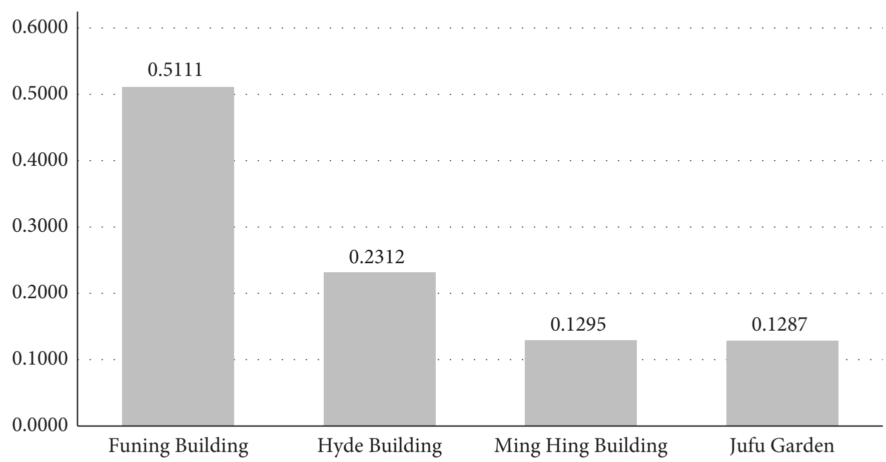

Figure 6: Site selection evaluation of Macau urban renewal projects (source: self-drawn by the author).

In transaction cost theory, projects with high capital, high time, and low space returns are often avoided in the selection of capital for renewal projects. The pure renewal investment amount cannot reflect the real cost of the project, so a better comparison can be made through the ratio between them and the time and renewal projects. Therefore, it can be seen that the Funing Building has the lowest cost input and the greatest benefit, while the Mingxing Building is at the bottom of the four projects and has the least benefit for businesses. The specific data are shown in Table 3.

5.2. Spatial Adaptability. Spatial adaptability mainly refers to the degree of environmental change and risk in the regeneration area. A good environment and low risk can bring a suitable renewal environment to the renewal area [34]. Based on local natural disasters in Macau, there are more storm surges and extreme weather as indicators. Protecting and improving the ecological environment and ecological balance can create a beautiful and comfortable living environment for the city. Urban renewal and sustainable development are inseparable, and urban renewal and urban safety cannot be ignored. Only a city with a good environment and safety can promote the organic renewal and development of the city.

The results (Figure 3) show that all four urban renewal sites are affected by storm surge, with Hyde House facing the greatest impact, which can cause significant economic damage and threaten the lives of residents in the renewal area.

5.3. Project Space Accessibility. Spatial accessibility refers to the accessibility of projects in the area to the outside world, emphasising spatial attributes and ignoring nonspatial factors, such as personal preferences, race, and class [35, 36]. The stronger this is, the more convenient it is to get to the project site and the more people it will attract. There are many methods for measuring accessibility, including the buffer method, the proportional method, the closest distance method, the two-step mobile search method, and the potential model. Different measurement methods target different research objects and have their own advantages [37]. The network analysis method [38] is used to measure the project accessibility of the urban redevelopment area. According to the different traffic modes, the accessibility of the road network is mainly divided into vehicle roads and pedestrian roads. For the convenience of the research, the pedestrian road network is used to calculate the 5 min and 15 min walking time as the degree of connectivity between the project point and the outside world. At the same time, the greater the reachable area from the project point, the greater the accessibility of the project accessories.

Table 5: The index system of site selection verification for urban renewal in Macau based on DEA.

Target layer	Criterion layer	Indicator layer	Indicator meaning	Source
Update site selection assessment	Economic and social investment	Building renewal investment	Reflect and update the construction base of the project	Visit statistics
		Percentage of ownership consent	Reflects the distribution of recognition among stakeholders	Visit statistics
	Spatial adaptation	Storm surge impact	Reflect the impact of disasters on renewal projects	Macau meteorological and geophysical bureau
		Air quality	Reflect the impact of the environment on the renewal project	Macau meteorological and geophysical bureau
	Spatial accessibility	Project accessibility	Reflects the potential of the project to attract people	Macau cartography and cadastre bureau
	Spatial diversity	Land use structure entropy	Reflect the diversity of land use types	Macau cartography and cadastre bureau
Update location verification	Economic and social output	Price after renovation	Verify project economic input and benefits	Macau real estate network
		Retrofit time	Verify the construction efficiency of the renovation project	Macau land and urban construction bureau
		Building area after renovation	Verify the changes in the spatial structure of the renovation project	Macau land and urban construction bureau
		Proportion of public service area	Assess the social benefits of the project	Macau land and urban construction bureau

Table 6: DEA-based verification data of urban renewal site selection in Macau.

Project	Funing Building	Hyde Building	Ming Hing Building	Jufu Garden
Building renewal investment (10,000 mop)	1120	1900	1225	1080
Proportion of owners agreeing (%)	100	85	100	100
Storm surge impact (feet)	2.5	3.0	2.5	2.5
Environmental pollution	36	36	29	36
Project accessibility (m^2)	128854	101057	166124	158188
Land use structure entropy	0.5041	1.0674	0.6452	0.4869
Price after update (average per square foot/10,000 mops)	1.63	0.95	0.72	0.53
Update time	4.5	5.0	5.0	4.0
Building area after updating (m^2)	3284.47	1716.92	617.02	753.17
Proportion of public service area	4.78	0	16.73	3.76

Source: made by the author.

Table 7: Effectiveness analysis of Macau urban renewal site selection benefit based on EAD.

Item	Overall benefit (θ)	Slack variable ($S-$)	Slack variable ($S+$)	Validity
Funing Building	1	0	0	DEA is strong and effective
Hyde Building	1	0	0	DEA is strong and effective
Ming Hing Building	1	0	0	DEA is strong and effective
Ju Fu Garden	0.922	31101.0514	2145.962	Not DEA valid

Table 8: Redundancy analysis of investment in the benefits of Macau urban renewal site selection.

	Item	Funing Building	Hyde Building	Ming Hing Building	Ju Fu Garden
Relaxed variable S-analysis	Construction renewal investment (10,000 mop)	0	0	0	0
	Proportion of owners agreeing (%)	0	0	0	3.359
	Storm surge impact (feet)	0	0	0	0.084
	Environmental pollution	0	0	0	1.26
	Project accessibility (m^2)	0	0	0	31096.348
	Land use structure entropy	0	0	0	0
	Summary	0	0	0	31101.051
Input redundancy rate	Building renovation investment (10,000 mop)	0	0	0	0
	Proportion of owners agreeing (%)	0	0	0	0.034
	Storm surge impact (feet)	0	0	0	0.034
	Environmental pollution	0	0	0	0.035
	Project accessibility (m^2)	0	0	0	0.197
	Land use structure entropy	0	0	0	0

Source: made by the author.

The results are shown in Figure 4. Mingxing Building has the widest 5-minute accessibility coverage, followed by Ju Fu Garden and Funing Building, and the Hyde Building has the lowest accessibility. From a spatial point of view, the location of the regeneration project in the central area of the city can maximize the flow of population to nearby cities. At the same time, the road network structure in the city centre is often denser, which promotes the evacuation of the population. The spatial location of the Mingxing Building is in the central area of northern Macau, so it is easier to radiate to the surrounding areas.

5.4. Project Spatial Diversity. Spatial diversity primarily refers to mixed land use. In the context of decaying cities, urban planning often assumes that a mix of land uses will reduce car use, increase active travel, and property values, resulting in a better urban environment. In the context of urban decay, mixed-use planning and development is an invaluable strategy for the rich and sustainable regeneration of the city center [39, 40]. The massive mix of land use, social, economic, and time use in the environment can be mixed and heterogeneous [41]. This study uses the Shannon–Wiener Diversity Index to measure the degree of diversification of land use types [42, 43]. A mix of land use types reduces vehicle use and increases the number of active trips and property values, resulting in better urban environmental conditions and a higher level of sustainability. The specific formula is as follows:

$$MLU = -\sum_{i=1}^{n} \frac{A_i}{A_t} \ln \frac{A_i}{A_t}. \tag{11}$$

Table 9: Analysis on the shortfall of benefit and output of Macau urban renewal site selection.

	Item	Funing Building	Hyde Building	Ming Hing Building	Ju Fu Garden
Slack variable $S+$ analysis	House price after renovation (average psf/10,000 mop)	0	0	0	0.911
	Retrofit time	0	0	0	0
	Building area after renovation (m^2)	0	0	0	2144.48
	Proportion of public service area	0	0	0	0.571
	Summary	0	0	0	2145.962
Underproduction rate	House price after renovation (average psf/10,000 mop)	0	0	0	1.719
	Retrofit time	0	0	0	0
	Building area after renovation (m^2)	0	0	0	2.847
	Proportion of public service area	0	0	0	0.151

Source: made by the author.

Among them, MLU is the Shannon–Wiener diversity index, *Ai* is the coverage area of a certain land use type, *At* is the total area in the buffer zone, and *n* is the total number of land use types in the buffer zone.

This study divides the urban land use types within the 300 metre coverage area based on the project centre point and calculates the Land Use Diversity Index of the regeneration project. The results are shown in Figure 5, where the Hyde Building, despite being close to the urban fringe, has a higher land use diversity index than other regeneration projects, regardless of motor traffic factors. In addition to being far from large public areas, the Hyde Building is easily accessible on foot. Different types of land use can be involved, such as commercial, park, recreational, and infrastructure land.

6. Comprehensive Evaluation and Verification of Project Site Selection

6.1. Comprehensive Evaluation of Project Site Selection. According to the spatial analysis of the urban renewal projects in the previous section, combined with the relevant economic and using social information from the Land Affairs Bureau, the four renewal projects are evaluated. The results (Table 4 and Figure 6) show that among the four projects, the renewal site of the Hyde Building has the highest score, followed by the Mingxing Building, and the Funing Building has the lowest score. It shows that, in the rationality of urban renewal site selection, the postrenewal benefit of the Hyde Building is the most significant, while the renewal benefits of the Funing Building and Ju F Garden are lower. And avoid sites, such as Funing Building and Ju Fu Garden. For the indicator dimension, the amount of investment in building renewal and the entropy of the land use structure are important indicators that affect the urban renewal effect. Although the Hyde Building has an owner-occupancy rate of 85% (the latter is 100%, but this survey is subject to the vote of the first owners' meeting) the storm surge had a greater impact and the project is less accessible. However, the Hyde Building stands out among the regeneration projects due to its high regeneration investment and diversity of uses.

Exploring the reason, it can be found that, in the entropy method of weight, the size of the weight value is mainly determined by the degree of dispersion of the sample size, and the size of the sample often affects the accuracy of the index weight. There are not many samples, so there is a certain deviation in the assignment of weights.

6.2. Verification of Project Site Selection Evaluation. In order to confirm the accuracy of the chosen evaluation model, this study used DEA for evaluation. Taking the updated location variable as the input element of the model and the updated socio-economic element as the output element, a dataset envelopment analysis model is constructed. It is worth noting that DEA has a temporal division in urban renewal, so it is not appropriate to use the two indicators of spatial benefits created by time and spatial benefits created by capital since both indicators involve data before and after renewal. Instead, the amount of investment in building renewal is used. The details are shown in Tables 5 and 6.

The results are shown in Table 7; in the four renewal projects, the three comprehensive benefit values of Funing Building, Hyde Building, and Mingxing Building are all equal to 1, and the slack variable $S-$ and slack variable $S+$ are both 0, which belong to DEA strong and effective, indicating that, relatively speaking, the DMU units of the three renewal projects are the most efficient, and only the comprehensive benefit value of Ju Fu Garden is less than 1, which is invalid for DEA, indicating that the input-output ratio is relatively inefficient.

The slack variable S-values of the three projects of Funing Building, Hyde Building, and Mingxing Building are all 0, so there is no investment redundancy problem in a relative sense. As a non-DEA effective decision-making unit DMU, Ju Er Fu Garden can further analyse its "input redundancy" situation. It can be seen from Table 8 that there are certain problems with the impact of storm surges and environmental pollution in Ju Fu Garden, and the risk prevention and control measures around the project should be strengthened to reduce the lack of space benefits caused by environmental problems.

The relaxation variable $S+$ values of the three projects of Funing Building, Hyde Building, and Ming Hing Building are all 0, so there is no problem of insufficient output in a relative sense. As a non-DEA effective decision unit DMU, Ju Fu Garden can further analyse its "insufficient output." It can be seen from Table 9 that, after the renovation of the old building, the housing price, renovation area and public service area proportion of Jufu garden all face a situation of insufficient output, and the insufficient output rate of the updated area is the largest, indicating that there is no relative input in the factors. In order to achieve the expected effective update area effect, there is still room for improvement in output efficiency.

7. Conclusion

Based on the perspective of spatial benefits, this study constructs an evaluation system for the benefits of Macau's urban renewal site selection from four indicators: socio-economic benefits, spatial accessibility, spatial diversity, and spatial adaptability. Based on the "input-output" theory, the DEA model is used to compare and verify the feasibility of the evaluation system:

(1) In terms of social and economic benefits, the proportion of owners of the four projects tends to be the same, and they all obtain new space benefits by expanding the building space, so as to achieve a rebalance in the distribution of space interests between owners and developers; and in terms of input costs, Funing Building uses The lowest capital and realizes the largest space expansion and the lowest input cost.

(2) In terms of spatial efficiency, Ju Fu Garden and Funing building both maintain a relatively

comfortable environment and have the highest spatial adaptability; Ming Hing Building is most convenient for communication with the surrounding environment and has the highest spatial accessibility; Hyde Building has better land use. The more the complex, the richer the spatial diversity. Therefore, the four projects have certain spatial advantages in different areas.

(3) In terms of comprehensive evaluation, Funing Building is the best option for urban renewal project site selection, showing strong comparative advantages in terms of social and economic benefits and spatial benefits, while Ju Fu Garden is the least suitable for site selection.

(4) In terms of input-output analysis, Ju Fu Garden has the worst input-output ratio among the four projects, mainly showing the insufficiency of urban environment construction, updated housing price, construction area, and public service ratio.

(5) The comprehensive evaluation method is consistent with the results of the DEA model. From the perspective of space, the Ju Fu Garden is the most inappropriate in the urban renewal site selection. It verifies the rationality of urban renewal site selection evaluation from the perspective of spatial benefit. Through comparative analysis, the comprehensive evaluation method needs to consider the interaction between indicators in the selection and construction of indicators. For example, "building renewal investment" should be understood and transformed into "spatial benefits created by time/funds," and it needs to be uniformly dimensionless weight assignment. The DEA model does not need to take their interaction into account, directly separates the two categories of "input-output," according to before and after updating, and replaces them with processing, which is more objective and convenient in the calculation process.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors are grateful for the Research project funded by the Macau Science and Technology Development Fund (FDCT-0039/2021/ITP).

References

[1] F. Camerin, "From "ribera plan" to "diagonal mar", Passing Through 1992 "Vila Olímpica". How Urban Renewal Took Place As Urban Regeneration in Poblenou District (Barcelona)," *Land Use Policy*, vol. 89, Article ID 104226, 2019.

[2] R. B. Fairbanks, "The Texas exception: san antonio and urban renewal,1949-1965," *Journal of Planning History*, vol. 1, no. 2, pp. 181–196, 2002.

[3] J. Schofield, *Cost-benefit Analysis in Urban and Regional planning*, Routledge, England, UK, 2018.

[4] E. H. W. Chan and G. K. L. Lee, "Contribution of urban design to economic sustainability of urban renewal projects in Hong Kong: c," *Sustainable Development*, vol. 16, no. 6, pp. 353–364, 2008.

[5] L. Y. Shen, J. Jorge Ochoa, M. N. Shah, and X. Zhang, "The application of urban sustainability indicators – a comparison between various practices," *Habitat International*, vol. 35, no. 1, pp. 17–29, 2011.

[6] D. La Rosa, R. Privitera, L. Barbarossa, and P. La Greca, "Assessing spatial benefits of urban regeneration programs in a highly vulnerable urban context: a case study in Catania, Italy," *Landscape and Urban Planning*, vol. 157, pp. 180–192, 2017.

[7] V. K. Manupati, M. Ramkumar, and D. Samanta, "A multi-criteria decision making approach for the urban renewal in Southern India," *Sustainable Cities and Society*, vol. 42, pp. 471–481, 2018.

[8] A. Cabanek, M. E. Zingoni de Baro, and P. Newman, "Biophilic streets: a design framework for creating multiple urban benefits," *Sustainable Earth*, vol. 3, no. 1, pp. 1–17, 2020.

[9] M. G. R. Pérez, M. Laprise, and E. Rey, "Fostering sustainable urban renewal at the neighborhood scale with a spatial decision support system," *Sustainable Cities and Society*, vol. 38, pp. 440–451, 2018.

[10] N. Chen and B. C. Zhou, "Old city renovation and historical and cultural heritage preservation under urbanization," *Economic Forum*, vol. 401, no. 1, pp. 39–42, 2007.

[11] J. F. Li, *Research on Model Selection and Comprehensive Benefit Evaluation of Urban renewal*, South China University of Technology, Guangzhou, China, 2019.

[12] Y. M. Cao, Z. Pang, and H. G. Yu, "Research on site selection assessment of urban renewal projects from the perspective of spatial performance," *Construction Economics*, vol. 41, no. 12, pp. 46–50, 2020.

[13] B. Jiang and Y. Wu, "Construction and application of a model for the assessment of urban village renewal potential," in *Proceedings of the 2021 China Annual Urban Planning Conference*, pp. 1061–1068, Chengdu, China, 2021.

[14] W. L. Zheng, Y. F. Xu, and R. B. Zheng, "Research on the performance evaluation of old village renovation projects--a case study of Baiyun District, Guangzhou City," *Geographical Research and Development*, vol. 38, no. 3, pp. 125–129, 2019.

[15] K. Z. Liu and L. T. Che, "Research on risk assessment of urban renewal projects in Shenzhen--based on hierarchical analysis method and fuzzy comprehensive evaluation method," *Modern Business*, vol. 545, no. 28, pp. 95-96, 2019.

[16] H. F. Liang, *Research on Site Selection of Urban Renewal Priority Transformation Projects Based on Hybrid Genetic algorithm*, South China Agricultural University, Guangzhou, China, 2017.

[17] X. Y. Ke, J. G. Li, C. Li, and C. Z. Sun, "Analysis of spatial and temporal variability of urban renewal performance and its influencing factors in Guangdong Province," *China Land Science*, vol. 36, no. 6, pp. 44–55, 2022.

[18] J. Ma, Y. Q. Shi, and Y. Q. Lu, "Evaluation of ecological compensation efficiency of Yangtze River economic belt based on four-stage data envelopment analysis (DEA) model,"

Science and Technology Management Research, vol. 42, no. 16, pp. 62–69, 2022.
[19] Q. J. Du and N. Li, "Efficiency and dynamic analysis of urban industrial air pollution control--based on three-stage super-efficient SBM-DEA model," *Journal of Hebei University of Geosciences*, vol. 45, no. 5, pp. 104–112, 2022.
[20] J. Li, H. Gao, Y. Li, X. Jin, and L. Liang, "Stock efficiency evaluation based on multiple risk measures: a DEA-like envelopment approach," *Journal of Systems Science and Complexity*, vol. 35, no. 4, pp. 1480–1499, 2022.
[21] T. Arsu, "Investigation into the efficiencies of European football clubs with bi-objective multi-criteria data envelopment analysis," *Decision Making: Applications in Management and Engineering*, vol. 4, no. 2, pp. 106–125, 2021.
[22] M. Rasoulzadeh, S. A. Edalatpanah, M. Fallah, and S. E. Najafi, "A multi-objective approach based on Markowitz and DEA cross-efficiency models for the intuitionistic fuzzy portfolio selection problem," *Decision Making: Applications in Management and Engineering*, vol. 5, no. 2, pp. 241–259, 2022.
[23] H. Zou, Y. Liu, B. Li, and W. Luo, "Sustainable development efficiency of cultural landscape heritage in urban fringe based on GIS-DEA-MI, a case study of wuhan, China," *International Journal of Environmental Research and Public Health*, vol. 19, no. 20, Article ID 13061, 2022.
[24] K. H. Huang, J. T. Pai, and J. H. Liu, "Study of performance assessment for urban renewal project in Taipei city," *International Review for Spatial Planning and Sustainable Development*, vol. 4, no. 1, pp. 64–77, 2016.
[25] M. Tang, J. Hong, X. Wang, and R. He, "Sustainability accounting of neighborhood metabolism and its applications for urban renewal based on emergy analysis and SBM-DEA," *Journal of Environmental Management*, vol. 275, Article ID 111177, 2020.
[26] X. M. Zhang, "Comparative analysis of data dimensionless methods in decision analysis," *Journal of Minjiang University*, vol. 33, no. 5, pp. 21–25, 2012.
[27] M. Wang, L. Yan, W. X. Zhang, and C. H. He, "Performance evaluation of urban renewal based on DEA method: taking the former xicheng district of beijing as an example," *Urban Development Research*, vol. 18, no. 10, pp. 90–96, 2011.
[28] L. F. Li, "Performance evaluation of urban renewal based on DEA: taking shenzhen as an example," *China Real Estate*, vol. 665, no. 36, pp. 55–61, 2019.
[29] Y. Zou, S. Tao, and W. H. Chu, "A generalized DEA model considering input and output indicator preferences," *Mathematical Practice*, vol. 52, pp. 1–10, 2004.
[30] Y. Liu, Y. S. Tian, and K. B. Zhou, "From one-year decision to multiple participation: a case study of the old town renewal of enning road, Guangzhou," *Urban Planning*, vol. 39, no. 8, pp. 101–111, 2015.
[31] D. Yan, Y. Y. Guo, and Y. L. Liang, "Discussion on the interest relationship among the three parties in the renovation of urban old residential areas: taking Shenzhen as an example," *Geographical Research*, vol. 40, no. 3, pp. 779–792, 2021.
[32] W. D. Huang, R. Yang, and C. F. Lin, "Governance transformation and institutional response in shenzhen's urban renewal evolution based on the perspective of "Cost-Benefit"," *Architecture*, vol. 180, no. 4, pp. 21–27, 2021.
[33] H. Gao, *Study on the Renewal Planning Strategy of Xi'an Xiaoyanta Area in the Perspective of Urban Public Safety*, Chang'an University, Xi'an, China, 2017.
[34] O. D. Cardona, M. K. van Aalst, J. Birkmann et al., "Determinants of risk: exposure and vulnerability," in *Managingthe Risks of Extreme Events and Disasters to advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*, C. B. Field, V. Barros, T. F. Stocker et al., Eds., pp. 65–108, Cambridge University Press, Cambridge, UK, and New York, NY, USA, 2012.
[35] X. T. Liu, "Review of spatial accessibility research," *Urban Traffic*, vol. 21, no. 6, pp. 36–43, 2007.
[36] W. Luo and F. Wang, "Measures of Spatial Accessibility to Health Care in a GIS Environment: Synthesis and a Case Study in the Chicago Region," *Environment and Planning B: Planning and Design*, vol. 30, no. 6, pp. 865–884, 2003.
[37] Z. N. Song, C. Wen, G. X. Zhang, and L. Zhang, "Spatial accessibility of public service facilities and its measurement method," *Advances in Geographical Sciences*, vol. 29, no. 10, pp. 1217–1224, 2010.
[38] T. Shi, J. Li, L. Ying, and H. Yin, "Accessibility analysis of urban park green space in Shenyang[J]," *Journal of Ecology*, vol. 35, no. 5, pp. 1345–1350, 2016.
[39] T. Shi, J. Y. Li, Y. Li, and H. Y. Yin, "Comparing measures of urban land use mix," *Computers, Environment and Urban Systems*, vol. 42, pp. 1–13, 2013.
[40] C. Turcu, "Local experiences of urban sustainability: researching Housing Market Renewal interventions in three English neighbourhoods," *Progress in Planning*, vol. 78, no. 3, pp. 101–150, 2012.
[41] E. Turnhout, M. Hisschemoller, and H. Eijsackers, "Ecological indicators: between the two fires of science and policy," *Ecological Indicators*, vol. 7, no. 2, pp. 215–228, 2007.
[42] G. Zhu, X. Wang, W. W. Zhang et al., "The impact of urban landscape pattern on bird communities: a case study of Lishui District in Nanjing," *Journal of Ecology and Rural Environment*, vol. 38, no. 3, pp. 327–333, 2022.
[43] T. Yoshida and K. Tanaka, "Land-use diversity index: a new means of detecting diversity at landscape level," *Landscape and Ecological Engineering*, vol. 1, no. 2, pp. 201–206, 2005.