

Research on Relocation Compensation and Whole Hospital Optimization Decision of Old Town Based on Particle Swarm Optimization Algorithm

Zesheng Zhang

School of Artificial Intelligence, Anhui University of Science and Technology, Huainan 232001, China

Abstract: The implementation of the "translational replacement" strategy in the renovation of existing bungalow blocks in the old city requires addressing issues such as relocation compensation, decision-making, cost-effectiveness judgment, and intelligent computing software framework design. This is a typical multi-objective optimization problem. Building models based on multiple algorithms to solve these problems can provide scientific relocation planning solutions for planning bureaus and developers, which has important practical significance. In the context of urbanization stock renewal, the impact of the "symbiotic courtyard" in the old city on redevelopment requires the design of a reasonable relocation compensation plan. Firstly, clarify the main factors and related constraints that affect residents' relocation, such as area, lighting, and repair. Assuming that residents' decisions are based on these factors and the rent remains unchanged for ten years. Using real estate economics and behavioral decision-making theory, the Logit model is used to quantify the probability of residents relocating, and the PSO algorithm is combined to optimize the model parameters. Obtain data through community research, fit Logit model parameters to determine compensation range, and consider factors such as spatial attributes and psychological price. Develop graded compensation plans for different residents and make dynamic adjustments. To maximize the economic benefits of the renovation of old city bungalow blocks, it is necessary to design relocation decisions based on compensation rules. The key is to maximize the number of vacant complete courtyards, adjacent to each other, and the total area while meeting the compensation rules. Considering factors such as plot attributes, courtyard relationships, costs, and time, it is assumed that residents follow compensation rules, plot courtyard attributes, and fixed development cycle costs. Using operations research and graph theory, a two-stage heuristic algorithm is adopted. Firstly, the "key residents" are determined through greedy search to generate an initial plan, and then the plan is optimized using genetic algorithm. Establish the objective function and constraints, and solve for the relocation plan as well as the costs, benefits, and other results.

Keywords: PSO, Dynamic factors, Fuzzy matrix, multi-objective optimization.

1. Introduction

In 2020, China's urbanization rate reached 63.89%, and urbanization construction has entered a stage of stock renewal to improve quality and efficiency[1]. On January 3, 2025, the State Council held an executive meeting to study and promote urban renewal work, proposing that "urban renewal is related to the improvement of urban appearance and living quality, and is an important lever for expanding domestic demand". It also called for accelerating the renovation of old urban communities, blocks, factories, and urban villages, and protecting and inheriting urban history and culture. Old urban residential areas often refer to "old city stock bungalow blocks". In mega cities and big cities, the existing bungalow blocks in old cities have diverse property rights and complex main bodies, and also involve issues such as historical protection and community governance[2]. In recent years, the renewal practice of bungalow blocks in the old city is mostly the gradual and acupuncture and moxibustion renewal work of "one thing one discussion", but the space reuse is not satisfactory, resulting in new difficulties and challenges.

Influenced by the traditional courtyard style architectural culture in China, the existing bungalow blocks in the old city are often organized into "quadrangle courtyards" as a whole unit. Currently, many courtyards have been vacated due to residents' relocation, but there are still residents in many courtyards who are unwilling to "move out of the old city, move upstairs" or accept monetary compensation, and prefer

to live locally, resulting in a "symbiotic" phenomenon of residents living in and vacated houses coexisting in one courtyard. This phenomenon poses difficulties for the redevelopment and utilization of vacant houses, as commercial development can cause significant disturbance to residents who live nearby and share the same courtyard. Moreover, a complete vacant courtyard is more conducive to diversified commercial development, achieving the redevelopment and improvement of the quality of old housing blocks.

The academia and industry have proposed a strategy of "shifting and replacing" existing residents between courtyards within the same block, which can not only meet the demands of residents living locally, but also vacate and replace the entire courtyard to better achieve the goal of courtyard redevelopment. A certain urban planning bureau invited a team to participate in planning and design work, assisting the planning bureau and developers in making intelligent relocation plans.

There are 107 courtyards of different sizes within an old block in the city, some separated from each other and some adjacent to each other. Each courtyard can be divided into different property plots for residential use. After removing non-standard private and disorderly construction spaces, there are a total of 484 suitable residential plots. Some residents in these plots have already moved out, while 113 households are still living, waiting for further relocation by the developer. The vacant plots within the block are jointly owned by the

planning bureau and the developer. The usual way to renew them is to rent them out to merchants for commercial, tourism, or office development. The planning bureau/developer collects rent to earn income, but renting out individual plots in the "symbiotic courtyard" is not as economically beneficial as renting out the entire courtyard[3].

2. Research on Relocation Compensation Scheme Based on Fuzzy Comprehensive Evaluation Method

This model aims to design a reasonable relocation compensation plan to increase residents' willingness to relocate. Considering that residents' willingness to relocate is influenced by various fuzzy factors, the fuzzy comprehensive evaluation method is adopted to quantify factors such as area, lighting, neighborhood relationships, historical emotional value, transportation convenience, and housing density through membership functions. The comprehensive satisfaction is calculated by combining the weights of each factor, and then the compensation plan is determined[4][5][6][7][8].

2.1. Analysis of influencing factors and inference of compensation rules

Residents who relocate usually hope to improve their living conditions, and the living area is an important factor. If the area is significantly reduced after relocation, it will affect the comfort of life. For example, for families who originally lived in a 100 square meter house, the reduction in area will lead to overcrowding. Developers need to control costs, and through market research and cost analysis, they can provide up to 30% more property plots than before. Therefore, the area compensation rule is

$$S_{\text{original}} \leq S_{\text{new}} \leq 1.3 \times S_{\text{original}} \quad (1)$$

Among them, S_{original} is the area of the original residential plot and S_{new} is the area of the relocated plot.

Lighting is a key factor affecting living comfort, and the order of lighting comfort given in the title is due south>due north>east wing>west wing. To quantify day lighting compensation, the orientation weight w is defined, with a weight of $w(\text{due south}) = w(\text{due north}) = 4$ assigned to the south and north orientations, a weight of $w(\text{East Box}) = 3$ for the east wing orientation, and a weight of $w(\text{West Wing}) = 2$ for the west wing orientation. Residents expect that the comfort level of natural lighting will not decrease during relocation, so it is required that the w value of the relocated land is not lower than that of the original land, i.e. $w_{\text{new}} \geq w_{\text{original}}$, where w_{original} is the weight of the original land orientation and w_{new} is the weight of the relocated land orientation.

When the area and lighting compensation cannot meet the residents' relocation willingness, the overall satisfaction of residents with the relocated land is low. To increase residents' willingness, developers need to repair and renovate houses. By designing a detailed survey questionnaire and conducting extensive surveys on residents, we aim to understand their psychological expectations for repair compensation under different degrees of insufficient area and lighting. Then, using statistical regression analysis and other methods, we obtain the function $C_{\text{repair}} = f(\Delta S)$ for the gap between repair compensation and resident satisfaction. At the same time,

considering the cost control of the developer, after cost accounting and market analysis, a limit of $0 \leq C_{\text{repair}} \leq 20$ million yuan was determined, where C_{repair} is the repair cost and ΔS is the difference in resident satisfaction.

2.2. Additional factors affecting

Residents have lived in the community for a long time, establishing deep relationships with their neighbors, forming a special social network and sense of belonging, such as neighbors taking care of each other's children and sharing life experiences. Moving away from the familiar neighborhood environment can make residents feel uneasy and lost, and they may refuse to relocate. To enhance residents' willingness, the "neighborhood similarity" indicator is introduced, prioritizing the centralized placement of residents in the same courtyard, maximizing the preservation of original neighborhood relationships, and increasing residents' sense of belonging and security.

Some plots have special historical and cultural memories that are closely related to residents' family history and community development, such as being the birthplace of local culture or witnessing important stages of community development. Residents have a deep emotional attachment to these plots and are unwilling to leave easily. By organizing a team of experts to qualitatively evaluate the historical and cultural value of the plot, the compensation coefficient for historical emotional value is quantified. For plots with high historical emotional value, additional compensation is given to compensate for residents' psychological losses.

The distance between the relocated land and the street directly affects the convenience of residents' travel. Close to the street, residents can easily reach public facilities such as bus stops, shops, schools, etc., saving travel time and costs; Long distances make travel inconvenient, such as increasing walking distance and transferring to other modes of transportation. Therefore, residents' willingness to relocate decreases with increasing transportation distance, and the compensation area can be adjusted according to the transportation distance.

The density of houses reflects the degree of crowding in the surrounding buildings of the plot. In high-density areas, the spacing between houses is small, and the lighting and ventilation conditions are poor. For example, in old residential areas, the ground floor houses are difficult to see sunlight and have poor ventilation, resulting in low living comfort. Residents prefer to live in environments with good lighting and ventilation, so for areas with high housing density, higher compensation should be given, such as increasing compensation area and raising repair costs.

2.3. Specific Forms of Mathematical Models

Considering the influence of additional factors, comprehensive satisfaction is introduced and calculated through fuzzy comprehensive evaluation method. The weights of each influencing factor are ω_1 (area), ω_2 (lighting), ω_3 (neighborhood similarity), ω_4 (historical emotional value), ω_5 (transportation distance), ω_6 (housing density), and $\sum_{i=1}^6 \omega_i = 1$. The membership degrees of each factor are μ_1 (area), μ_2 (lighting), μ_3 (neighborhood similarity), μ_4 (historical emotional value), μ_5 (transportation distance), μ_6 (housing density), so the comprehensive satisfaction is:

$$U = \sum_{i=1}^6 \omega_i \mu_i \quad (2)$$

Among them:

$$\begin{cases} \mu_1(S_{\text{new}}) = \begin{cases} \mu_{10}, & S_{\text{new}} = S_{\text{original}} \\ \mu_{10} + \frac{S_{\text{new}} - S_{\text{original}}}{0.3S_{\text{original}}} (1 - \mu_{10}), & S_{\text{original}} < S_{\text{new}} \leq 1.3S_{\text{original}} \end{cases} \\ \mu_2(w_{\text{new}}) \propto w_{\text{new}} \\ \mu_3 = \omega_3 \\ \mu_4(\alpha) = \frac{\alpha-1}{M-1} \quad M \text{ is the maximum value of } \alpha \\ \mu_5(d) = \frac{d_0-d}{d_0} \quad d_0 \text{ represents the maximum acceptable travel distance for residents} \\ \mu_6(\rho) = \frac{\rho_0-\rho}{\rho_0} \quad \rho_0 \text{ represents the maximum housing density acceptable to residents} \end{cases} \quad (3)$$

When U reaches the psychological threshold U_0 of residents, they are willing to relocate. If $U < U_0$, it is necessary to adjust the compensation plan, such as increasing the repair cost C_{repair} , etc. For example, by increasing repair costs, residents' satisfaction with areas and lighting may be improved, leading to an increase in overall satisfaction U and reaching the psychological threshold U_0 of residents. M is the maximum value of α .

3. Research on the Redevelopment and Utilization of Old House Blocks

To achieve the redevelopment and improvement of the quality of old residential areas, it is necessary to free up more complete courtyards through the "relocation and replacement" strategy. From the perspective of developers, on the one hand, they hope to have the most complete courtyards left vacant after the final relocation, with complete courtyards as adjacent to each other as possible and the total area as large as possible, in order to obtain greater rental income; On the other hand, efforts should be made to complete the relocation within the cost budget, while reducing the number of households to be relocated and lowering the relocation costs.

3.1. Analysis of influencing factors and constraints

The topological relationship between courtyards determines the adjacency of the entire courtyard. The more vacant courtyards that are adjacent to each other, the greater the economic benefits of the developer. Therefore, in the relocation decision, it is necessary to consider how to make the vacant courtyards as adjacent as possible through reasonable relocation.

The relocation cost affects the feasibility of the relocation plan. The relocation investment of the developer includes relocation communication costs (coordination and other communication costs for each relocated household are 30000 yuan), repair and renovation costs (the upper limit for repair and renovation of the relocated land is 200000 yuan for each relocated household), area loss (during the relocation process, the area overpaid by the developer to residents should be converted into the developer's economic loss based on the potential rent of the property plot), and time loss for relocation and development (it takes 4 months for each relocated household).

Residents' adaptability to the new living environment and future development plans around the plot may also have an impact on relocation decisions, but relative to the above factors, they will not be given priority consideration in this

model for the time being. Further analysis can be conducted based on actual situations in the future.

Area compensation:

$$S_{\text{original},i} \leq S_{\text{new},i} \leq 1.3 \times S_{\text{original},i} \quad (4)$$

For each household i , the area $S_{\text{new},i}$ of the relocated land must be between the original residential land area $S_{\text{original},i}$ and 1.3 times the original residential land area. This constraint ensures that the area of the relocated residents is not less than the original area, meeting their basic living needs, while preventing developers from overcompensating and controlling costs.

Light compensation:

$$w_{\text{new},i} \geq w_{\text{original},i}, \forall i \quad (5)$$

The orientation weight $w_{\text{new},i}$ of each household's relocated land must not be lower than the orientation weight $w_{\text{original},i}$ of the original residential land. This ensures that the lighting comfort of residents does not decrease after relocation and increases their willingness to relocate.

Repair compensation:

$$0 \leq C_{\text{repair},i} \leq 20, \forall i \quad (6)$$

When the area and lighting compensation are insufficient, additional repair costs $C_{\text{repair},i}$ are required to increase residents' willingness to relocate. But the repair cost must be controlled between 0 and 200000 yuan to avoid developers bearing excessive costs.

Cost constraints:

$$C_{\text{total}} = \sum_{i=1}^n C_{\text{move},i} \leq 2600 \quad (7)$$

The total cost C_{total} of the developer is the sum of the relocation costs $C_{\text{move},i}$ of all n relocated residents, including

$$C_{\text{move},i} = 3 + C_{\text{repair},i} + 365 \times \frac{S_{\text{new},i} - S_{\text{original},i}}{S_{\text{original},i}} \times$$

Rental unit price $\times 4$. It must be within the budget range, that is, not exceeding 26 million yuan. This is the economic constraint of the developer, which determines the feasibility of the relocation plan.

For each resident i , there must be a suitable relocation site that meets all the compensation rules mentioned above. In practical situations, the area and orientation of vacant property plots in various courtyards are determined and limited, and developers may not be able to find suitable relocation sites for all residents. If a relocation site that meets the compensation rules cannot be found, the resident will not relocate.

3.2. Objective Function

Maximizing the number and total area of vacant courtyards, minimizing the number of relocated households, and maximizing the number of adjacent courtyards. Therefore, the

objective function is constructed as follows:

$$\text{Maximize } \sum_{j \in \text{Vacant courtyard}} A_j + \lambda \sum_{(j,k) \in \text{Adjacent courtyard}} A_j A_k - \beta N \quad (8)$$

$$\text{s. t. } \begin{cases} S_{\text{original},i} \leq S_{\text{new},i} \leq 1.3 \times S_{\text{original},i} \\ w_{\text{new},i} \geq w_{\text{original},i}, \forall i \\ 0 \leq C_{\text{repair},i} \leq 20, \forall i \\ C_{\text{total}} = \sum_{i=1}^n C_{\text{move},i} \leq 2600 \end{cases} \quad (9)$$

Among them, $\sum_{j \in \text{Vacant courtyard}} A_j$ is the sum of all vacant whole courtyard areas, and A_j is the area of the j -th vacant whole courtyard. This section reflects the total area of the complete courtyard formed after relocation. The larger the courtyard area, the greater the space available for rental or other commercial development, which may bring higher rental income. $\lambda = 0.2$ is the adjacent reward coefficient, and $\sum_{(j,k) \in \text{Adjacent courtyard}} A_j A_k$ measures the collaborative value of the entire adjacent hospital. Adjacent courtyards can form larger commercial areas, enhance overall attractiveness and competitiveness, and thus increase the economic benefits of developers. By introducing this item, it is encouraged to make vacant entire courtyards as adjacent as possible in relocation decisions. It is a weight coefficient used to balance the number of relocated households with the overall goals of the hospital, where N is the number of relocated households. The function of $-\beta N$ is to minimize the number of households to be relocated while pursuing the overall number and area of the hospital, in order to reduce relocation costs. The value of needs to be adjusted according to the actual situation to achieve a balance between different goals.

Adopting Particle Swarm Optimization (PSO) algorithm. This algorithm simulates the behavior of bird flocks searching for food, with each particle representing a possible relocation combination[9][10]. Through cooperation and information

sharing between particles, it continuously searches in the solution space to find the optimal relocation combination, in order to meet the requirements of leaving as many complete courtyards as possible after the final relocation, being as adjacent to each other as possible and having the maximum total area, while minimizing the number of relocated residents. This algorithm is suitable for large-scale nonlinear optimization problems. The relocation decision problem for residents in old neighborhoods involves complex constraints such as courtyard topology, relocation costs, compensation rules, etc. The PSO algorithm can find optimal solutions under these complex conditions. Figure 1 provides an intuitive explanation of the working principle of position and velocity updates in PSO. In PSO, each particle represents a candidate solution in the search space. In a one-dimensional search space, the i -th particle has two guiding vectors at the i -th iteration: position vector $X_i^t = [X_{i1}^t, X_{i2}^t, \dots, X_{iN}^t]$ and velocity vector $V_i^t = [V_{i1}^t, V_{i2}^t, \dots, V_{iN}^t]$. During the optimization process, the position and velocity of each particle are updated based on two reference positions: the individual optimal position $pbest_i = [pbest_{i1}, pbest_{i2}, \dots, pbest_{iN}]$ previously visited by the particle and the global optimal position $gbest_i = [gbest_{i1}, gbest_{i2}, \dots, gbest_{iN}]$ found by the entire population.

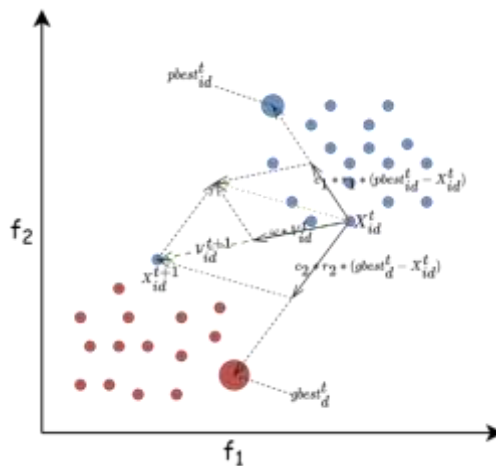


Figure 1 PSO iteration process diagram

According to the individual optimal position and the global optimal position, the velocity and position update formula of

the n th particle in the t th iteration are as follows:

$$\begin{cases} \mathbf{V}_{id}^{t+1} = \omega \cdot \mathbf{V}_{id}^t + c_1 \cdot r_1 \cdot (\mathbf{pbest}_{id}^t - \mathbf{X}_{id}^t) + c_2 \cdot r_2 \cdot (\mathbf{gbest}^t - \mathbf{X}_{id}^t) \\ \mathbf{X}_{id}^{t+1} = \mathbf{X}_{id}^t + \mathbf{V}_{id}^{t+1} \end{cases} \quad (10)$$

Among them, t represents the current number of iterations; ω is a nonlinear inertia weight; c_1 and c_2 are the cognitive acceleration constant and social acceleration constant, respectively; r_1 and r_2 are random numbers uniformly distributed within the interval $[0,1]$.

3.3. Model solving

(1) Read the property rights and land parcel information of the old block, determine the number of residents to be relocated and available land parcels for relocation, and assign directional weights to the land parcels.

(2) Set the number of particles, inertia weight, learning factor, maximum iteration times, and fitness improvement threshold, randomly generate particles and initialize speed, and record the historical and global optimal positions.

(3) Based on the relocation combinations represented by particles, determine the complete set of vacant courtyards, calculate the total area, collaborative value, and number of relocated households, substitute them into the objective

function to obtain fitness values, and update the historical and global optimal positions.

Update the velocity and position of particles according to the formula.

(4) Check the constraint conditions: Check whether the updated particle positions meet the constraints of area, lighting, repair, cost, and relocation feasibility. If they do not meet the requirements, adjust them.

(5) Check if the preset number of iterations has been reached or if the fitness improvement is less than the threshold. If it meets the requirements, output the optimal relocation combination. Otherwise, return to step (3).

(6) Determine the courtyard and plot of the relocated residents, calculate the vacated whole courtyard area, total cost, final income, and profit.

3.4. Partial Results

PSO iterative convergence diagram, as shown in Figure 2.

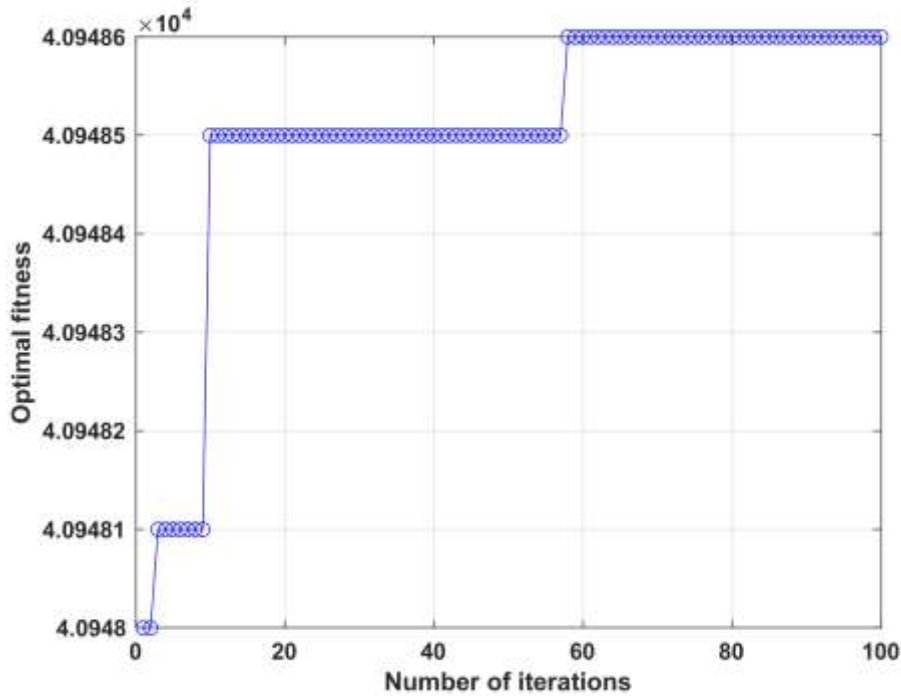


Figure 2 PSO Iterative Convergence Diagram

Relocation Plan, as shown in Table 1.

Table 1 Relocation Plan, as shown in Table 1

Original ID	ID after relocation
8	416
104	429
131	335
161	83
161	268
169	469
177	188
218	11

The distribution of the original plot and target area for the

245	368
283	1
284	86
296	53
375	402
417	80
429	98
430	430
435	388
456	375

relocation drama title is shown in Figure 3.

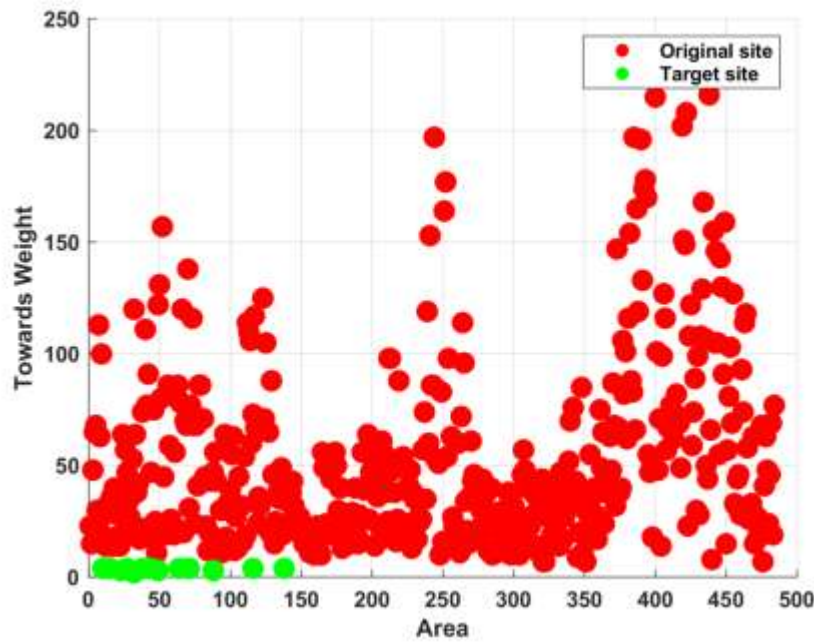


Figure 3 Distribution of the original plot and target area for the relocation drama title

4. Conclusions

The model in this article comprehensively considers various factors such as compensation rules, courtyard relocation relationships, relocation costs, neighborhood relationships, historical emotional value, and transportation convenience. It can fully reflect the complexity of actual relocation decisions and make the plan more feasible in reality. The fuzzy comprehensive evaluation method can handle the ambiguity of subjective feelings and quantify factors that are difficult to accurately quantify through membership functions and weights. Particle swarm optimization algorithm can handle complex constraint conditions (such as compensation rule constraints, cost constraints, etc.) and find optimal solutions in complex environments. Monte Carlo simulation can consider uncertainties such as rental income and relocation costs. By conducting random simulations, it comprehensively analyzes various possible relocation situations. The model constructs a multi-objective objective function to seek a balance between maximizing the overall benefits of the hospital and minimizing the number of relocated households, taking into account the interests of developers and the difficulty of relocation implementation. The model can be extended by adding fuzzy factors, optimizing algorithms, or introducing dynamic factors to adapt to the needs of different scenarios.

References

- [1] He, S., & Wang, Y. (2022). Urban renewal and heritage conservation in Chinese cities: Tensions and reconciliation. *International Journal of Heritage Studies*, 28(7), 779 - 796.
- [2] Zhang, X., & Wu, F. (2021). Gentrification, displacement, and urban renewal in Chinese cities: A comparative study of Shanghai and Guangzhou. *Urban Studies*, 58(13), 2795 - 2813.
- [3] Li, Y., & Zhao, X. (2023). Community - based urban renewal strategies in China: A case study of old urban residential areas. *Habitat International*, 130, 102692.
- [4] Wang, L., & Zhang, M. (2022). A Fuzzy Comprehensive Evaluation Model for Urban Renewal Relocation Compensation Plan Based on Entropy - Weighted Analytic Network Process. *Journal of Urban Planning and Development*, 148(4), 04022031.
- [5] Li, H., et al. (2021). Fuzzy Comprehensive Evaluation of Residents' Satisfaction with Relocation Compensation in Shantytown Reconstruction. *Sustainability*, 13(18), 10438.
- [6] Chen, X., & Zhao, Y. (2023). A Fuzzy Decision - Making Model for Urban Relocation Compensation Schemes Considering Multiple Stakeholder Preferences. *Journal of Civil Engineering and Management*, 29(3), 321 - 332.
- [7] Wu, S., et al. (2022). Fuzzy Comprehensive Evaluation of the Feasibility of Relocation Compensation Plans in Urban Redevelopment Projects. *International Journal of Environmental Research and Public Health*, 19(16), 10169.
- [8] Liu, J., & Sun, X. (2024). An Improved Fuzzy Comprehensive Evaluation Method for Relocation Compensation Plans in Historic Urban Areas. *Heritage Science*, 12(1), 1 - 13.
- [9] Kennedy, J., & Eberhart, R. C. (1995). Particle swarm optimization. *Proceedings of ICNN International Conference on Neural Networks*, 1995., 4, 1942 - 1948.
- [10] Parsopoulos, K. E., & Vrahatis, M. N. (2002). Particle swarm optimization in multiobjective problems. In *Proceedings of the IEEE international conference on systems, man, and cybernetics (Vol. 4, pp. 3036 - 3041)*. IEEE.