Application and Decision Support of Multi-Objective Optimization Algorithm in Urban Landscape Planning

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Abstract. In a city, the urban landscape is a very important part. If foreign tourists come, the urban landscape will be their first impression of the city. Therefore, the planning and design of the urban landscape is very important. There are certain defects in the traditional urban landscape, such as not beautiful enough, poor environmental quality and so on. In order to better guide the urban landscape planning and design, this article uses the multi-objective optimization algorithm, taking a certain district of a city as an example, based on the ArcGIS platform, simulates the landscape planning of the district, and evaluates the planning scheme combined with the sensitivity analysis method. The results show that the reasonable layout of landscape planning in this area can improve the quality of urban environment, improve the quality of life of residents, increase employment opportunities, increase fiscal revenue, and achieve the purpose of optimizing urban functions and rationally allocating urban resources. The experimental results show that the urban landscape designed by applying the multi-objective optimization algorithm has the highest praise rate of 89.6% in terms of quality of life.

Keywords: Multi-Objective Optimization, Urban Landscape, Landscape Planning, Decision Support

1. Introduction

With the rapid development of urbanization, the problem of urban land use has become increasingly prominent. As one of the important means to solve this problem, urban landscape planning organically combines urban landscape spatial structure, functional layout and ecological environment to achieve optimal allocation and sustainable development of urban land.

In recent years, scholars at home and abroad have carried out in-depth research in the field of urban landscape planning and achieved rich results. Among them, Mallick, Suraj Kumar has been working on the Predict-Adapt-Restore (PAR) approach to the future exploitation of the city and the sustainability of every developing city in the world. Advocacy for sustainable, resilient and fast urban change in the development of urban areas needs to be defined clearly and clearly in a particular context [1]. Liu,

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Congru used a multi-dimension approach to city landscape design. Finally, it was found that the regression standard deviation is 0.567, the standard value is 0.753, and the f-test value is 0.655. Thus, the performance of vision characteristic in multi-dimension non-linear landscape design is better [2]. Li Shijia made an evaluation and simulation of urban greenbelt landscape planning project by PSO-BP (Particle Swarm Optimization-Backpropagation Algorithm). It is proved that this method not only has a certain storage and learning ability, but also can make simple predictions on human behavior, so that project evaluation is more comprehensive, scientific and reasonable [3]. However, in the specific application process, due to the huge number of decision variables, traditional optimization algorithms are difficult to solve.

Based on the ArcGIS platform, this paper conducts landscape planning simulation and program evaluation for a certain district in a certain city. Through the simulation, the problems existing in the process of land use change in this area are found, such as the rapid expansion of construction land and the rapid reduction of cultivated land, etc., and some improvement suggestions are adopted for these problems. At the same time, combined with the sensitivity analysis method, the landscape planning scheme of this area is evaluated, and the best urban landscape planning scheme is determined.

2. Research Methods

Taking a certain district of a certain city as an example, the article selects a number of urban landscape planning indicators, takes the rationality of the landscape planning layout, the quality of life of residents, employment opportunities and financial income as the objective function, uses the multi-objective optimization algorithm to solve the model, and combines the sensitivity analysis method to evaluate the planning scheme [4]. This article uses ArcGIS software as a platform to establish a landscape planning layout model. The model mainly involves urban landscape planning layout indicators and urban land use types. The article takes the objective function as the goal, and the model is established as shown in formula (1).

$$x = g(y;\theta) \tag{1}$$

In formula (1), θ is a model parameter. At the same time, formula (2) can also be used to minimize this function.

$$\min_{\theta} K(\theta) = \frac{1}{k}\sum_{i=1}^{k} K(x_i, y_i;\theta) \tag{2}$$

In formula (2), K represents the number of training samples.

To make sure that the pattern is reasonable, it can be classified as building land and unbuilt land. Building land consists of business, residence, educational, science and so on, while the non-building land consists of forestry, wetland and eco-conservation. To show the features of these categories more clearly, classify the building land into two categories: housing, common administration, utility, and other areas, which are classified as eco-conservation, forest-woodland and wetland, and then assign a weighting factor to them [5].

Classifying land use types according to ecological reserve, forest land and wetland, and set corresponding weight coefficients to obtain the weight coefficient table of land use types. Then, the weight coefficients of each type are substituted into the model to obtain the corresponding objective function value. On this basis, the weighted comprehensive value of the land use type is obtained by calculation [6].

Classifying land use types according to urban construction land, forest land and cultivated land, and set corresponding weight coefficients; on this basis, the weight coefficients of each element are substituted into the model to obtain the weighted comprehensive value of each land use type; finally, the comprehensive weight value of each land use type is obtained through calculation. The final result of the urban landscape planning layout model can be obtained by adding the weights of each planning scheme [7].

The evaluation of urban landscape planning layout is mainly through the analysis of three indicators of key construction areas, non-key construction areas and ecological reserves in the overall land use planning of the study area. According to the above weight coefficients, the contribution rate values of each planning scheme on different land use types under different index weight coefficients are calculated, and finally the proportion of different schemes on each index is calculated [8].

3. Landscape Planning Scheme Design and Evaluation

The landscape planning scheme is a regional ecological planning scheme under multi-objective and multi-constraint conditions, and the constraints involved are: ecological protection red lines, basic farmland protection areas, urban construction land expansion boundaries, forest park ecological protection red lines, water system protection red lines, etc. Based on the multi-objective optimization algorithm, using the spatial analysis tool of ArcGIS, according to the above constraints, the spatial planning model of the regional ecological protection red line, basic farmland protection area, urban construction land expansion boundary and other elements was constructed, and the simulation was carried out simulation. The regional planning plan improves the ecological environment quality of forest parks, improves the quality and speed of the expansion boundary of urban construction land, and improves the uniformity and coordination of the expansion boundary of urban construction land through rational layout of ecological construction land. From the simulation results, it can be seen that the planning scheme is feasible in terms of achieving ecological protection goals and improving the uniformity of urban construction land expansion boundaries [9].

It can be seen from the spatial planning model of the planning scheme that it is feasible to rationally arrange various ecological lands in a certain area and improve the service function and biodiversity level of the ecosystem. However, it should be noted that urban landscape planning should not only focus on the protection of the ecological environment, but also consider factors such as urban economic development and the quality of life of residents [10].

3.1 Scope of Urban Landscape Planning

The scope of urban landscape planning should generally include two parts: The first is the land for ecological system, that is, the red line of ecological protection and the basic farmland protection area; the second is the land for urban construction, that is, the expansion boundary of urban construction land and the red line of ecological protection of forest parks. The requirements of the above two aspects should be fully considered in urban landscape planning. The measurement and calculation should be made according to the related rules on the area of ecology, the extension limit of city building land, and the green line of eco-conservation of forest park. In terms of their properties and usage, we shall differentiate them from each other in the city landscape planning [11].

3.2 Planning Objective Function

The regional ecological protection red line refers to the mandatory protection boundaries demarcated for areas with important ecological functions in the region in accordance with relevant laws and regulations in order to ensure regional ecological security, mainly including the red line of ecological protection of forest parks, basic farmland protection areas, expansion boundaries of urban construction land, etc. In the regional landscape planning, the rational layout of ecological construction land and the improvement of the ecological environment quality of forest parks are important means to achieve the goal of regional ecological protection [12]. Forest parks are the most important natural green space system in the city and the most important habitat for biodiversity conservation. In the process of urban development, due to reasons such as urban expansion and construction land expansion, the ecological environment quality of forest parks has continued to decline, and biodiversity has been severely damaged [13]. The basic farmland protection area refers to the cultivated land designated for the protection of basic farmland, food production, and agricultural economic development in a certain area in order to ensure the special protection of cultivated land by the state or local governments, mainly including permanent basic farmland, general farmland and garden land, etc. In urban landscape planning, priority should be given to expanding the boundary of construction land, rationally distributing various types of ecological land, and improving the quality of life of urban residents [14]. The extension border of city building is defined as an extension of the area defined by the city during the course of developing city, industry, residence and so on, which are mainly used for city building, village housing and forestry industry. Reasonable distribution of city building land extension limits can enhance the living quality of city dwellers [15].

3.3 Space Optimization Algorithm

In urban landscape planning under multi-objective and multi-constrained conditions, multi-objective optimization algorithms have outstanding advantages. Genetic algorithm and particle swarm optimization algorithm are the most commonly used optimization algorithms. Genetic algorithm utilizes the mutual relationship among individuals in the population, and evaluates the pros and cons of individuals through the fitness function, thus generating new individuals. Particle swarm algorithm uses the optimal solution produced by particles iteratively within a finite time as a collection of optimal solutions in the population [16]. Taking the spatial planning model as a group of multi-objective optimization problems and using genetic algorithm to solve them can effectively solve the multi-objective optimization problems in urban landscape planning. The article simulates the urban landscape planning model under different planning objective functions, different constraints, and different geographical conditions, and conducts a decision-making analysis of the spatial planning model [17]. The simulation results show that with the forest park as the core, it radiates to the surrounding area, forming a belt-shaped ecological construction pattern that increases successively from the center to the periphery; with the expansion boundary of urban construction land as the core, it radiates to the surrounding areas, forming a belt-shaped urban construction pattern that decreases from the center to the periphery.

3.4 Evaluation Method

Regional ecological planning schemes can achieve ecological protection goals and improve the uniformity, coordination and coordination of urban construction land expansion boundaries, but urban landscape planning should also consider factors such as urban economic development and residents' living quality. Therefore, while realizing the goal of ecological environment protection, the regional ecological planning scheme should also take into account the needs of urban economic development and residents' quality of life [18].

In the process of urban landscape planning, multi-objective optimization algorithm can be used to comprehensively evaluate multiple objectives [19]. This method overcomes the shortcomings of traditional algorithms that only consider a single target, and also takes into account the mutual influence between multiple targets. When the above method is used to evaluate the regional ecological planning scheme, it can not only obtain the results of regional ecological environmental protection, improve the level of urban economic development, and meet the quality of life of residents, but also obtain the best scheme of landscape planning scheme design [20].

4. Analysis of the Experimental Results of Landscape Planning and Design

In the experimental part, the article first conducted a survey and statistics on the evaluation indicators of urban landscape, with a total of 500 respondents. The survey content was what they considered the most important indicators of urban landscape. The results are shown in Table 1. Then, the satisfaction of residents near the urban landscape with respect to the quality of life and air quality was collected, and the results are shown in Figures 1 and 2.

Table 1. Urban Landscape Evaluation Indicators

Object	Index	Number of people	Percentage
Cityscape	Air quality	110	22%
	Quality of life	107	21.4%
	Economic benefits	88	17.6%
	Overall beautiful	105	21%
	Perfect function	90	18%

It can be seen from Table 1 that 110 people believe that air quality is the most important indicator, accounting for 22%, which is the highest. 107 people think that the quality of life is the most important indicator, accounting for 21.4%, ranking second. 105 people think that overall beauty is the most important indicator, accounting for 21%, ranking third. The number of people with economic benefits is the least, with 88 people accounting for 17.6%.

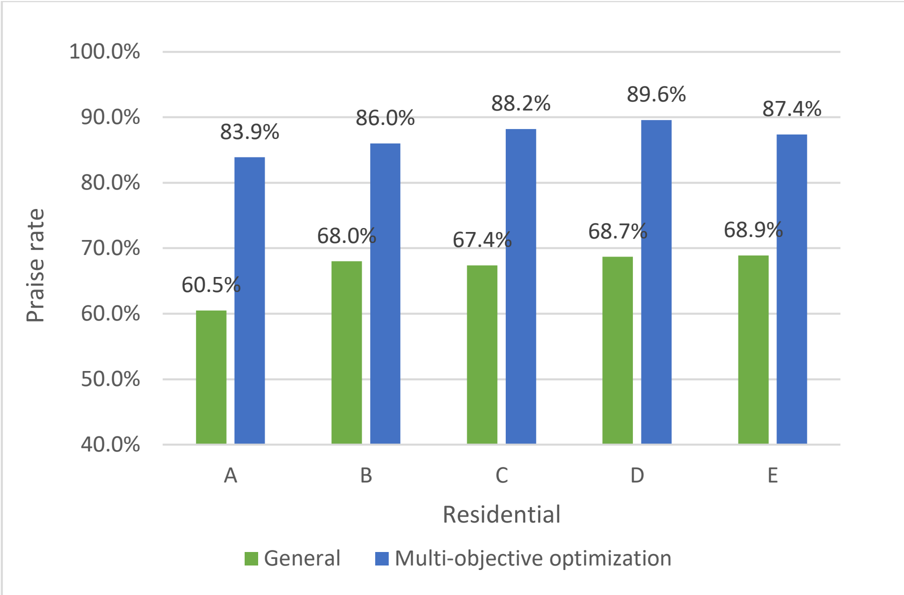

Fig.1 Quality of life

It can be seen from Figure 1 that among the residential buildings near the general urban landscape, the residents of residential building A have the lowest favorable rate of 60.5% for the quality of life, residential building E has the highest favorable rate of residents at 68.9%, and the average favorable rate of residents of the five residential buildings is calculated to be 66.70%; among the residential buildings near the urban landscape designed under the multi-objective optimization algorithm, the residential building D has the highest favorable rate of 89.6%, and residential building A has the lowest favorable rate of 83.9%, and the calculated average favorable rate is 87.02%. It can be seen that the urban landscape designed under the multi-objective optimization algorithm can effectively improve the quality of life of nearby residents.

It can be seen from Figure 2 that among the residential buildings near the general urban landscape, the residents of residential building A have the lowest favorable rate of air quality at 70.2%, the highest favorable rate of residents of residential buildings B and E is 78.6%, and the calculated average favorable rate is 74.72%; among the residential buildings near the urban landscape designed under the multi-objective optimization algorithm, residential building C has the highest favorable rate of 89.4%, and residential building E has the lowest favorable rate of 85.6%, and the calculated average favorable rate is 87.48%. It can be seen that the urban landscape designed under the multi-objective optimization algorithm can effectively improve the air quality nearby. Finally, the experiment is carried out from the perspective of economic benefits, and the index used is GDP. The experimental object is a city where the urban landscape designed by applying the multi-objective optimization algorithm is located, and its GDP in the next six months is simulated. The results are shown in Figure 3, and the unit in the figure is 100 million yuan.

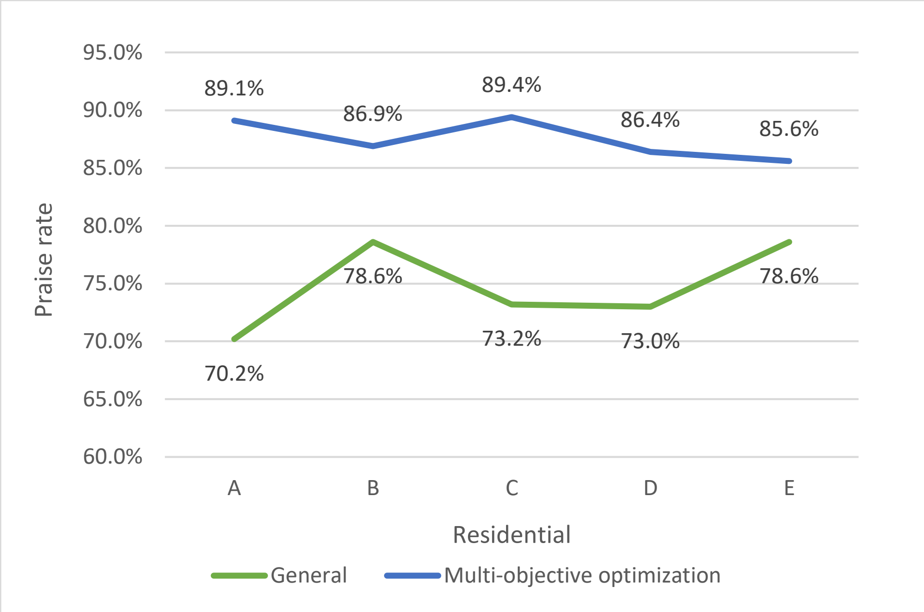

Fig.2 Air quality

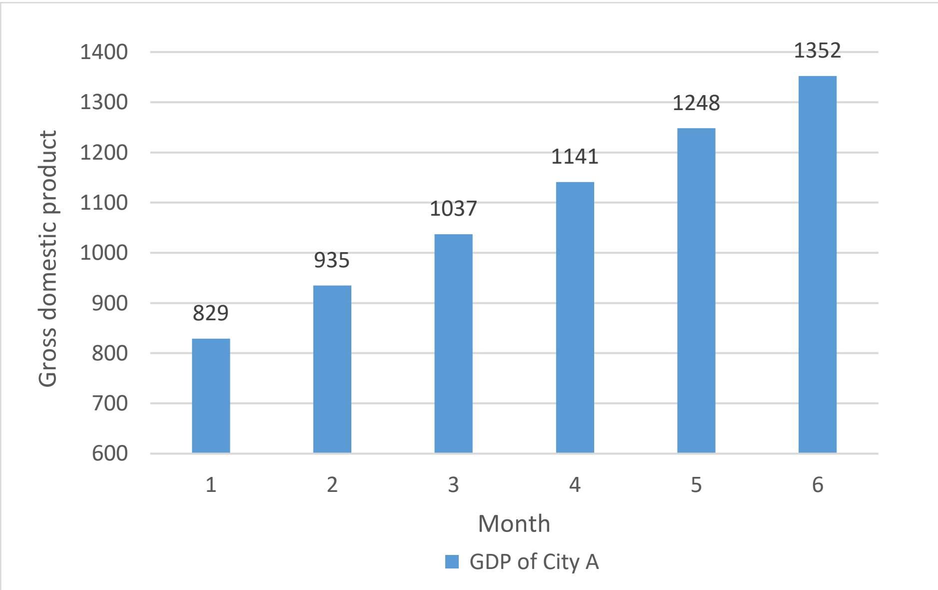

Fig.3 GDP Statistics

It can be seen from Figure 3 that after applying the multi-objective optimization algorithm to design the urban landscape in city A, its GDP has been rising steadily in half a year, only 82.9 billion yuan in the first month, but reached 135.2 billion yuan in the sixth month , a difference of 52.3 billion yuan, a total of 654.2 billion yuan in half a year. It can be seen that the application of multi-objective optimization algorithm to design urban landscape can effectively improve the economic benefits of the city.

Since urban landscape planning directly affects the economic benefits of the city and the quality of life of residents, the influence of various factors must be taken into account in urban landscape planning. In the article, the planning scheme is evaluated by sensitivity analysis method, and it can be concluded that the planning scheme has certain feasibility and rationality.

(1) Economic benefit analysis: After evaluating the planning scheme through the sensitivity analysis method, it can be seen that the construction area of the planning scheme is relatively large, and the construction cost is high, but the impact on the ecological environment is small, and the quality of life of urban residents can be guaranteed not to be affected; at the same time, the planning scheme can increase employment opportunities and promote regional economic development.

(2) Analysis of quality of life of residents: After evaluating the planning scheme through the sensitivity analysis method, it can be seen that the planning scheme can provide a high-quality living environment for residents in the area, increase residents' income, and improve the quality of life of residents; at the same time, the planning scheme can also improve the regional ecological environment, and then realize the healthy and sustainable development of the city.

The comprehensive evaluation method is mainly realized by quantifying the degree of influence of different factors on the objective function. In the article, the degree of influence of different factors on the objective function is quantitatively analyzed by means of sensitivity analysis, so as to achieve the purpose of comprehensive evaluation of planning schemes. Through the comprehensive evaluation, it can be found that the optimization algorithm based on NSGA-II has the best effect in the comprehensive evaluation, and it is more in line with the actual situation. The calculation of the algorithm is based on formula (3).

$$N = n + (h_m(a+1) - h_m(a-1)) / (h_m^{\max} - h_m^{\min}) \tag{3}$$

In formula (3), N is the degree of crowding, and $h_m(a+1)$ represents the value of the objective function after the individual is sorted.

Through the application research of multi-objective optimization algorithm in urban landscape planning, not only can urban landscape planning be more reasonable and scientific, but also the efficiency and effect of urban landscape planning can be improved. The multi-objective optimization algorithm used in this article can also be applied to the research of urban ecological environment construction and regional economic development, so as to better guide urban landscape planning and design, improve the quality of life of urban residents, promote urban health, and achieve sustainable development.

5. Conclusions

This paper adopts multi-objective optimization algorithm, taking a certain district of a city as an example, simulates the urban landscape planning scheme, and evaluates the planning scheme by combining the sensitivity analysis method. The results show that urban landscape planning based on multi-objective optimization algorithm can realize the sustainable development of urban landscape, and the human-centered landscape layout is an important way to achieve sustainable development. Various factors should be considered in landscape planning, such as land use type, natural conditions, human conditions, etc., to organically combine natural and human factors to realize the harmony and unity of man and nature. At the same time, there are also some shortcomings: due to the lack of actual research and analysis of the community, the diversity of optimization schemes is not enough; the optimization effect of some regional landscape planning schemes is not obvious. Therefore, the article believes that community investigation and research work should be strengthened; reasonable planning schemes should be formulated in combination with local actual conditions and residents' needs when carrying out landscape planning and design.

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