Integrated spatial regulation strategy of blue-green body space for urban ecological restoration

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Abstract: With the acceleration of urbanisation, urban ecological environment problems are becoming more and more prominent. To address this problem, the study proposes a spatial integration and regulation strategy for the blue-green main body, including the quality improvement of the ecological environment in the blue-green space and the construction of ecological barriers in the blue-green space. The hierarchical analysis method is also used to assess its effectiveness. The results show that among the spatial integration and control strategies of blue-green space proposed by the study, the scores of the technical indicators of the quality improvement strategy of blue-green space ecological environment are all higher than 70, the scores of the economic indicators are all higher than 85, and the scores of the environmental indicators are all higher than 75. At the same time, the scores of the technical indicators of the strategy of constructing ecological barriers in blue-green space are all higher than 75, the economic indicators are all higher than 70, and the environmental indicators are all higher than 70. This indicates that the proposed regulation strategies of the study show high scores and advantages in technology, economy and environment. These strategies provide strong support and guarantee for the improvement of ecological environment quality in blue-green space and the construction of ecological barriers.

1. Introduction

With the acceleration of urbanisation, urban ecosystems are facing unprecedented pressure and challenges [1]. Over-exploitation, pollution and destruction in the process of urbanisation have led to the disruption of the balance of urban ecosystems, the decline of environmental quality, the reduction of biodiversity, and the increasing severity of climate change [2-3]. In order to maintain the ecological balance and sustainable development of cities, ecological restoration has become one of the important tasks in urban planning and construction. As an indispensable part of the urban ecosystem, the blue-green subject space is of great significance for the ecological restoration of cities. The blue-green main space refers to the natural ecosystems such as water bodies and green spaces in the city, as well as the urban artificial ecosystem closely connected to the natural ecosystem. The blue and green main space plays a crucial role in urban ecological construction. It not only provides fresh air and a pleasant environment, but also effectively reduces the urban heat island effect, enhances the ecological function and sustainability of the city. Blue and green main spaces help to improve the quality of life of urban residents, promote harmonious coexistence between humans and nature, and play important ecological functions in urban ecosystems, such as purifying air, regulating climate, and protecting biodiversity. In order to achieve ecological restoration in the city, the study proposes the integrated regulation of blue-green subject spaces, which considers the various ecosystems in the city as a whole, and adopts a variety of means, such as planning, design and management, with a view to achieving a balanced and sustainable urban ecosystem.

2. Integrated spatial regulation of blue-green subject space for urban ecological restoration

2.1 The relevance of blue-green subject space to urban ecological restoration

Blue space and green space are indispensable ecological elements in the city, and together they provide rich ecological service functions for urban residents [4]. Firstly, both blue space and green space are important places for urban residents' recreation. The water system in the blue space can carry out water sports, fishing and other water activities, while the green space of the green space can be used for people to take a walk, have a picnic, play and so on. In addition, the blue space and green space also have a variety of ecological services such as regulating the urban microclimate, purifying the air and nourishing water. In terms of spatial layout, blue space and green space also have a close connection [5].

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Generally speaking, the blue space is distributed in the centre of the city or along the main rivers, while the green space is mainly distributed in the edge of the city or suburbs. This distribution is conducive to urban residents being able to enjoy these ecological services conveniently in their daily lives. At the same time, the blue space and green space can also be connected to each other through ecological corridors, forming a huge ecological network and making the natural environment of the city more complete and coordinated. The schematic diagram of the association between blue and green space and ecological restoration is shown in Figure 1.

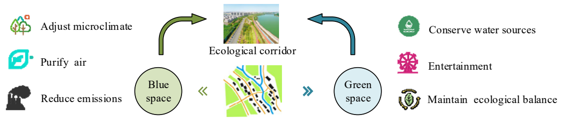


Fig.1 The relationship between blue-green space and ecological restoration

While bringing prosperity and economic benefits, the rapid development of cities often brings about the destruction of the ecological environment. This is mainly due to the serious impact of land development and human activities on the natural environment in the process of urbanisation, leading to the deterioration of the urban ecological environment [6]. Therefore, the restoration and protection of the urban ecological environment has become an important task in China's urban development. In this process, the blue-green main space plays a crucial role as an important carrier of urban ecological restoration [7]. Blue-green main space refers to the sum of water system and green space in the city, which can effectively improve the urban environment and reduce the pressure of urban ecological environment. For example, wetlands can absorb and purify rainwater and reduce the pressure on the urban drainage system, while parks and green spaces can provide urban residents with a good place for leisure and relaxation, and at the same time improve the air quality of the city. In addition, the planning and construction of blue-green main space is also conducive to improving the ecological efficiency of the city [8-9]. Through scientific and reasonable layout and design, the blue-green main space can provide urban residents with a better living environment, and at the same time provide the necessary ecological services for the urban ecosystem. For example, the existence of parks and wetlands can attract birds and other organisms, forming biodiversity in the city and thus maintaining ecological balance. In addition to this, the blue-green subject space is also an important means for the continuation of the city's cultural heritage and historical lineage. In the process of planning and construction, attention should be paid to the integration with local culture and history, so that it can become an important carrier for displaying urban characteristics and culture.

2.2 Spatial Integration and Regulation Strategy for Blue-Green Subjects

With regard to the ecological restoration of the city, the study proposes an integrated control strategy for the blue-green main space, which mainly includes the quality improvement of the ecological environment in the blue-green space and the construction of ecological barriers in the blue-green space. In terms of improving the quality of the ecological environment in the blue-green space, it mainly includes the restoration of the ecological substrate in the blue-green space, the associated restoration of water ecosystems and the restoration of the green ecosystem into a network. The restoration path of the ecological substrate mainly treats rivers and lakes, soil and wetlands, and at the same time improves the green space rate. On the basis of combining the existing natural water system, it follows the topography and respects the original natural pattern of mountains, water, forests, fields, lakes and grasses, and avoids filling in ponds, changing drains, destroying forests, encroaching on farmland and changing the texture of the original roads as much as possible. The associated restoration of water ecosystems is in accordance with the principle of setting land, people and production by water, fully analysing the large and small water environments within the township, and focusing on the gradient stratification of the water system so as to carry out precise and refined management. In the network restoration of green ecosystems, for the green ecological resources that are geographically adjacent and have compatible species habits, while protecting and restoring them, it is also necessary to consider connecting pieces, belts, and points of green space to form a network system with good ecology and high biodiversity. For suburban piecemeal green space ecosystems, the ecological patches of protection forests along roads, water bodies and important farmland are strengthened by means of the restoration of damaged protection forests, the transformation of forest phases, the ecological restoration of groves and the screening and research of dominant plant species.

With regard to the construction of ecological barriers in blue-green space, the study focuses on restoring natural elements such as mountains, rivers, fields and lakes and ponds in order to achieve the continuity and integrity of blue-green space. Firstly, important ecological reserves and ecologically sensitive areas are protected through measures such as upgrading the forest coverage of mountainous areas, establishing woodland corridors and communicating green ecological spaces. At the same time, the ecological barrier effect of centralised greening will be enhanced by making use of local characteristic vegetation. In addition, through the implementation of sponge city concepts and practices, water sources are protected, water safety and hygiene protection barriers are constructed, and water quality of water bodies is optimised. In addition, the agricultural production environment will be optimised through the protection of arable land and the development of a wide variety of cash crops and water-saving crop cultivation. For the assessment of the spatial integration of blue-green main body regulation strategy, the study introduced the Analytic Hierarchy Process (AHP) [10]. Mainly from the

Table.1 The index weight of the blue and green subject spatial integration control strategy

Criterion layer	Weight	Element layer	Weight	Indicator layer	Weight
A1 Technical indicators	0.4	B1 Technical reliability	0.49	C1 Management Difficulty	0.45
				C2 Technical Readiness	0.55
		B2 Technical applicability	0.25	C3 The difficulty level of large-scale promotion	1.00
		B3 technical sophistication	0.26	C4 Plant survival rate	0.55
				C5 Bank slope stability	0.45
A2 Economic indicators	0.3	B4 Economic cost	1	C6 Construction costs	0.6
				C7 Maintenance cost	0.4
A3 Environmental Indicators	0.3	B5 Water purification	0.65	C8 TN removal rate	0.5
				C9 COD removal rate	0.5
		B6 Ecological Restoration	0.35	C10 vegetation coverage	1.0

technical, economic and environmental aspects of in-depth analysis, the establishment of a comprehensive evaluation index system to assess the spatial integration of blue-green subject control strategy. The comprehensive evaluation adopts a four layer indicator system framework and establishes an ecological restoration technology comprehensive evaluation indicator system based on "target layer criterion layer element layer indicator layer", in order to comprehensively and multi angle reflect the characteristics of the technology. The first layer is the target layer, which is the comprehensive evaluation of repair technology. The second layer is the criterion layer, which sets four different dimensions: environmental indicators, economic indicators, technical indicators, and social indicators to comprehensively reflect the evaluation objectives of the comprehensive evaluation. The third layer is the element layer, which further refines and decomposes the criterion layer, grouping indicators that evaluate the same aspect or goal into one category, optimizing the indicator system, and making the objectives clearer. The fourth layer is the indicator layer, which is used to evaluate the specific indicators of ecological restoration technology. Firstly, the scoring is carried out by experts in relevant fields, and the index assignment is obtained, and the comprehensive score of the assessment object is calculated as shown in equation (1).

$$D_i = S_Z \cdot \sum\nolimits_{Z=1}^{K} (D_{2Z} \cdot W_Z) \qquad (1)$$

In equation (1), D_i represents the composite score of the assessment object, and D_{2Z} is the normalised value of an indicator in the criterion layer. K indicates the number of indicators in the criterion layer, and z represents the first z indicator. denotes the weight of the W_Z z th indicator of a technical criterion layer, and S_Z represents the benchmark value of the indicator. D_{2Z} The calculation is shown in equation (2).

$$D_{2Z} = \sum\nolimits_{y=1}^{j} (D_{3y} \cdot W_y) \qquad (2)$$

In Equation (2), D_{3y} represents the normalised value of an element of a technology at the element level, j is the number of elements at the element level, y represents the y element at the element level, and W_y represents the weight of the y indicator at the element level of a technology. D_{3y} The calculation is shown in equation (3).

$$D_{3y} = \sum\nolimits_{x=1}^{i} (D_{4x} \cdot W_x) \qquad (3)$$

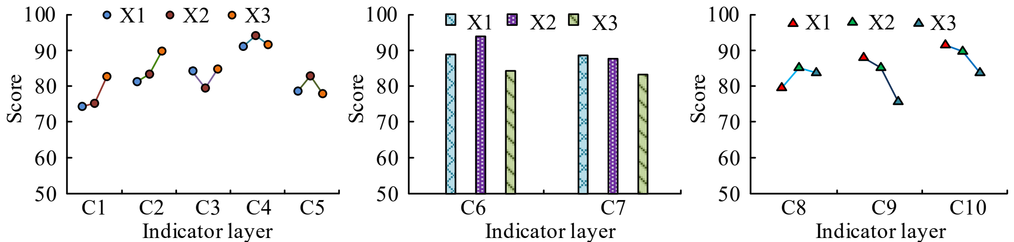
In Equation (3), D_{4x} represents the normalised value of the x th indicator of a technical indicator layer, i represents the number of indicators of a technical indicator layer, x represents the x th indicator of an indicator layer, and W_x represents the weight of the x th indicator of a technical indicator layer. D_{4x} The calculation is shown in equation (4).

$$D_{4x} = \frac{F_x}{S_x} \qquad (4)$$

In Eq. (4), F_x represents the scoring system of the first x indicator of a technical indicator layer, and S_x is the benchmark value of the first x indicator. The weights of the indicators of the spatial integration control strategy of the blue-green main body are shown in Table 1.

3. Experimental analysis of spatial integration and regulation strategies for blue-green subjects

In order to verify the effectiveness of the integrated spatial regulation strategy of the blue-green main body, the study firstly scored the applicability of the quality improvement strategy of the blue-green spatial ecological environment, and the assessment results are shown in Figure 2. In Figure 2, X1 indicates the ecological substrate restoration of blue-green space, X2 indicates the associated restoration of water ecosystems, and X3 indicates the restoration of green space ecosystems into a network From Figure 2(a), it can be seen that the scores of the technical indicators of the quality enhancement strategies of the ecological environment of the blue-green space are all higher than 70, of which, the plant survival rate of the three strategies scores the highest, which is respectively as high as 91.03, 93.63, and 92.14 points . As can be seen from Figure 2(b), the scores of the economic category indicators of the ecological environment quality enhancement strategies for blue and green spaces are all higher than 85. Among them, the construction cost scores are the highest, and the construction cost of the associated restoration of water ecosystems scores as high as 95.28 points. As can be seen from Figure 2(c), the scores of the environmental category indicators of the proposed strategies are all higher than 75. Among them, the average biodiversity enhancement rate of each strategy is as high as 89.25 points. After weighting calculation, it can be obtained that the comprehensive score of the ecological substrate restoration strategy of blue-green space is as high as 87.36 points, the total score of the associated restoration of water ecosystems is as high as 88.96 points, and the total score of the greenland ecosystem into a network restoration is as high as 86.17 points. The high score of the blue and green space ecological environment quality improvement strategy indicates that it helps to improve the vegetation coverage rate and the ecosystem stability. At the same time, it is feasible and acceptable in the economic aspects, and can be implemented within the scope of reasonable investment. Moreover, this strategy is able to effectively promote the increase of biodiversity and improve the stability and resistance of ecosystems.



(a) Technical indicators scoring (b) Economic indicator rating (c) Environmental indicator rating

Fig.2 Evaluation results of quality improvement strategies for ecological environment

The study continues to score the applicability of ecological barrier construction strategies in blue-green space, and the assessment results are shown in Figure 3. In Figure 3, Y1 represents enhancing forest coverage, Y2 represents using local characteristic vegetation to enhance the barrier effect, Y3 represents constructing a barrier for water source safety and hygiene protection, and Y4 represents protecting arable land. From Figure 3(a), it can be seen that the scores of the technical category indicators of the ecological barrier construction strategy are all higher than 75, among which, the scores of the technical indicators of constructing a water source safety and hygiene guarantee barrier are all higher than 85. As can be seen from Figure 3(b), the scores of the economic indicators of the ecological barrier construction strategy are all higher than 70 points. Among them, the highest economic indicator score of protecting arable land reached 87.69 points. The base stability of enhancing forest cover is slightly lower, with a score of 72.36. As can be seen from Figure 3(c), the scores of the environmental indicators of the ecological barrier construction strategies are all higher than 70 points. Among them, the vegetation cover of each strategy has the highest score, which is as high as 85.61 points on average. After weighting calculation, it can be obtained that the total score of the strategy of enhancing forest cover is as high as 79.06 points. The total score of using local characteristic vegetation to enhance the barrier effect is as high as 82.33 points. The total score of building a barrier for water source safety and hygiene is as high as 83.62 points. The score for the strategy of protecting arable land is as high as 83.08 points. It shows that the ecological barrier construction strategy of blue-green space has high applicability in the three aspects of technology, economy and environment. The various indicators of the ecological barrier construction strategy have achieved high scores, indicating that the strategy can effectively protect the ecological environment and reduce the impact of human activities on the ecosystem. By establishing ecological barriers, ecological protection areas can be delineated, development and destruction behaviors can be restricted, and the integrity of rare and endangered species and ecosystems can be protected. At the same time, this strategy can promote sustainable economic development while protecting the ecological environment. By carrying out ecological and economic industries such as ecotourism and ecological agriculture, providing employment opportunities, increasing local income, and achieving a virtuous cycle of ecological environment protection and economic development.

4. Conclusion

Urban ecological environment issues are important factors that affect the sustainable development of cities. In order to solve the problem of ecological restoration, a series of comprehensive control strategies for blue-green main spaces have been proposed, including the improvement of the ecological environment in blue-green spaces and the improvement of the ecological environment in blue-green spaces. The results showed that in the evaluation of strategies for improving the ecological environment quality in blue-green spaces, the plant survival rate scores of each strategy were as high as 91.03, 93.63, and 92.14, respectively. The construction cost for the restoration of related aquatic ecosystems is as high as 95.28. The average score of biodiversity enhancement for each strategy is as high as 89.25. The comprehensive scores of each quality enhancement strategy were as high as 87.36, 88.96, and 86.17, respectively. At the same time, in the strategic evaluation of the construction of ecological barriers in blue-green spaces, the scores of various technical indicators for building water source safety and health protection barriers were all higher than 85 points. The highest score for the economic indicator of farmland protection is 87.69 points. The basic stability for improving forest coverage is slightly lower, with a score of 72.36. Vegetation coverage scored the highest among each strategy, with an average of 85.61 points. The total scores of various ecological barrier construction strategies were as high as 79.06, 82.33, 83.62, and 83.08, respectively. The method proposed by the research institute makes urban planning more focused on ecological environment protection and sustainable development. By rational planning and layout of blue-green spaces, the quality of urban ecological environment can be effectively improved, vegetation coverage can be increased, water ecosystems can be improved, and biodiversity protection can be promoted. Meanwhile, by evaluating the effectiveness of different strategies, the most suitable strategy can be selected to address specific ecological restoration issues. However, urban planning and ecological restoration require significant investment as well as professional technical and human resources. Therefore, the government, enterprises, and the public should work together to strengthen cooperation and promote the implementation of comprehensive control strategies for blue and green main spaces.

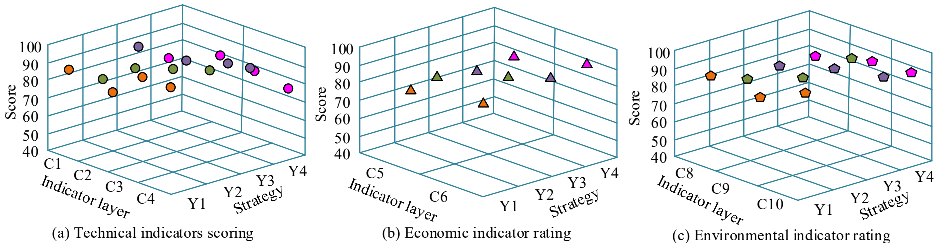


Fig.3 Evaluation results of ecological barrier construction strategies in blue-green spaces

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