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CONSTRUCTION OF URBAN WETLAND ECOLOGICAL LANDSCAPE PLANNING MODEL BASED ON MSPA ANALYSIS METHOD

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Highlights

- Design a new urban wetland ecological landscape planning model.
- In this paper, MSPA analysis method is used to construct the urban wetland ecological landscape planning model.
- The model proposed in this paper shows that the model can improve the accuracy of urban wetland ecological landscape planning and shorten the planning time.

Abstract. The traditional method does not accurately select the ecological landscape pattern index of urban wetland, which leads to the problems of low accuracy and long planning time, in order to solve this problem, an urban wetland ecological landscape planning model based on MSPA analysis method is constructed. By analyzing the basic components of urban wetland ecological landscape, such as patch density, aggregation index, dispersion index, average fractal dimension, landscape segmentation, shape index, spread index and Shannon diversity index, MSPA analysis method is used to extract the core area, patch area and ring of urban wetland. According to the extraction results, the minimum function of cloud fusion transformation of three-dimensional wetland ecological landscape is calculated, and the function is used to calculate the three-dimensional translation transformation amount and rotation matrix of three-dimensional wetland ecological landscape model. The data in the three-dimensional model are used for wetland ecological landscape planning, so as to complete the construction of wetland ecological landscape planning model. The simulation results show that the urban wetland ecological landscape planning accuracy of the model is high and the planning time is short.

Keywords: MSPA analysis method, urban wetland, ecological landscape, plaque area, rotation matrix.

Introduction

As a city, as a place where a large number of people live, its ecological environment is undoubtedly worrying. Since the industrial revolution in the 18th century, with the continuous improvement of science and technology and industrialization, the proportion of urban population has continued to increase, urban land has continued to expand, production and life have been concentrated, and this has brought a series of ecological and environmental problems: grassland degradation, soil erosion, soil desertification, river wetlands are replaced by artificial surfaces, and the area of impervious land is gradually expanding. At this stage, the area of impervious land in many developed cities at home and abroad is as high as 60%. Chemical fertilizers, livestock and poultry pollution, etc. flow into wetlands along with surface runoff. Large amounts of domestic water and industrial wastewater are directly discharged into rivers without treatment, and the pollution rate completely exceeds. The river wetland's own purification ability has caused the wetland water quality to decline, the area shrinks, and the wetland ecological environment is seriously damaged (Hersperger et al., 2021; Khosravi & Hemami, 2019; Li et al., 2020). The most prominent external manifestation of the process of urbanization and socio-economic development is the huge changes in the urban landscape. At the same time, it has also caused problems such as the large-scale reduction of urban river wetlands and the disappearance of wetland landscape features. In fact, a large part of the wetlands in many cities have already been developed. No longer exists. Therefore, the construction of urban wetland ecological

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landscape has been urgent. The urban wetland landscape will become an important place for urban residents to feel the breath of nature and experience the wildness of nature. In the urban wetland landscape design, while paying attention to its landscape form, it must first pay attention to its ecology. Wetland systems, like other ecosystems, are composed of biological communities and inorganic environments. To build an urban wetland ecosystem with self-organization, self-sustainment and self-design capabilities, we must respect the ecological process of wetlands. Wetland is a moving rather than static ecosystem. This system includes a series of complex physical, chemical, and biological processes such as hydrology, biogeochemistry, ecosystem dynamics, and species adaptation. Ecosystem coordination, biological settlement, and functions sufficient time is needed to realize the establishment and development of other ecological processes (He et al., 2018). In addition to purifying water quality, controlling and degrading pollution, urban wetlands also have other functions of wetlands, such as mitigating floods, regulating local microclimates, and producing economic products. The combination with tourism and ecological agriculture can bring direct or indirect effects Economic benefits. Due to the multiple functions and benefits of the urban wetland system, it is necessary to pay attention to its functionality as an ecological system in landscape design. According to the key points of planning and design, one or two main goals can be selected and designed in a targeted manner (Rashid & Aneaus, 2019). Especially when restoring and rebuilding the disappeared wetland, the reconstructed wetland must be able to perform all or most of the functions of the disappeared wetland. Therefore, the construction of urban wetland ecological landscape planning model is imperative (Chang, 2019; Kurtaslan, 2020).

Song et al. (2019) took the Yangxi River Wetland in Chenzhou, Hunan as an example, designed an urban wetland landscape ecological planning model. The main content of the Yangxi River Wetland Planning in Chenzhou includes the construction of "One Belt and Seven Districts", which incorporates the unique characteristics of urban construction in the urban wetland planning. The concept of sponge cities and green roofs reduces soil and water pollution in the form of plant enrichment and ecological floating islands, combined with the new concept of forest eco-tourism, and highlights the uniqueness of regional culture in urban wetland design. Explore a design optimization plan that suits the development needs of urban residents and meets the requirements of wetland landscape ecological planning. Zeng and Xu (2020) constructed a riverside ecological landscape planning model at different scales after flood disasters, analyzed the scale effect from the definition of the scale effect in the field of ecology, and divided the scale into spatial scale, time scale, and organizational scale in the dimension of scale extension. A spatial scale planning model and a non-spatial scale (time scale and organization scale) planning model based on the spatial scale information characteristics of the riverfront playable ecological landscape group were constructed at different scales. The case analysis results show that the constructed model can be accurate and comprehensive. Extract the spatial scale information characteristics of the riverside playable ecological landscape group, improve the land utilization rate, and realize the scientific, diversified and humanized riverside ecological landscape planning (Berred et al., 2020). However, the accuracy of urban wetland ecological landscape planning of the above two models is low, and the planning time is longer.

The traditional method does not accurately select the ecological landscape pattern index of urban wetland, which leads to the problems of low accuracy and long planning time, this paper takes solving the problems existing in the traditional methods as the research goal, and designs an urban wetland ecological landscape planning model based on MSPA analysis method. Therefore, this model has the advantages of high planning accuracy and short planning time. The overall design scheme of the model is as follows:

(1) By analyzing the basic components of urban wetland ecological landscape, such as patch density, aggregation index, dispersion index, average fractal dimension, landscape segmentation, shape index, spread index and Shannon diversity index, MSPA analysis method is used to extract the core area, patch area and ring of urban wetland.

(2) According to the extraction results of urban wetland core area, patch area and annual rings, the minimum function of cloud fusion transformation of three-dimensional wetland ecological landscape is calculated, and the three-dimensional translation transformation amount and rotation matrix of three-dimensional wetland ecological landscape model are calculated by using this function. The data in the three-dimensional model are used for wetland ecological landscape planning, so as to complete the construction of wetland ecological landscape planning model.

(3) Through simulation experiments, the planning accuracy and planning time of urban wetland ecological landscape with different models are compared.

1. Extraction of ecological landscape information of urban wetland based on MSPA analysis method

1.1. MSPA analysis method

Morphological Spatial Pattern Analysis (MSPA) is an image processing method, which is derived from mathematical morphology. It is an image analysis subject based on lattice theory and topology. It is used for geometric shape analysis and description tool. The prerequisite for the realization of the morphological spatial pattern analysis method is to convert the regional landscape type map into a raster binary map, making it a completely mutually exclusive landscape category (Hoversten & Swaffield, 2019; Macdonald & King, 2018). Through the application of a series of mathematical morphological algorithms, including corrosion, expansion and skeleton extraction algorithms, the original binary image will be classified, and the regions with connected significance will be identified and produced, which can be classified into up to 7 mutually independent landscape types. Through these 7 landscape types to describe the pattern characteristics of the target landscape type. This algorithm focuses on highlighting the geometric, pattern and topological space characteristics of a certain type of image element. The seven types of ecological landscape structure are core area, patch, pore, edge, ring road, bridge and branch line. The specific meaning and ecological significance of each are shown in Table 1.

1.2. Landscape pattern index selection

Based on the analysis of core areas, patches, pores, edges, loops, bridges and branches by MSPA analysis method, the urban wetland ecological landscape pattern index is selected, so as to lay a solid foundation for the follow-up urban wetland ecological landscape planning (Dai & Zhuang, 2019).

According to the principle of adapting measures to local conditions, the research selects two types of landscape pattern indexes to describe: One is the level index of landscape patch type. After image processing in Arc Map 10.2, the vector data of the landscape ecological type is converted into raster data, and it is calculated by Fragstats 4.2., including patch density (PD), aggregation index (AI), dispersion index (IJI), average fractal dimension (FRAC_MN), landscape division degree (DIVISION). The second category is the landscape level index, including the shape index (LSI), the spread index (CONTAG), and the Shannon diversity index (SHDI) (Balbi et al., 2019; Zhao et al., 2019).

Plaque density (PD)

$$PD = \frac{N_i}{A}. \tag{1}$$

Patch density (PD) represents the number of patches per 100 hm^2 of land. The higher the patch density, the

Table 1. Types of morphological spatial pattern structure

Structure type	Ecological characteristics	Ecological significance
Core	The core of the green vegetation coverage area is a certain distance from the green boundary	The core area indicates a potential, suitable and complete habitat for urban biological species, and represents a node in the ecological network. In the urban area, the core area usually corresponds to the large parks in the urban area, the forest reserves (forest parks) around the city, the scenic spots and so on
Islet	Relatively isolated and small green patches	The patch pixel is a green landscape area, but it is too small to contain the core, that is, all the isolated parts that disappear after the corrosion operation, and the possibility of exchange and flow of internal organic matter and external organic matter is less. In general, the attached green space in the city, such as residential green space, Street Center Park, road square green space, etc., shows the characteristics of patches
Perforation	The inner patch edge area is the transition area between the core area and non green landscape patches	Porosity is the periphery of the area that blocks the movement of species in the core area. It introduces a kind of edge effect instead of allowing species to enter the core forest area. In urban green landscape, the pore area is the core area, and the green landscape is affected by human activities or natural conditions, resulting in the edge of vegetation degradation
Edge	External boundary of core area	In the urban environment, the edge is the intersection zone between the core area of green landscape and the outside world, such as the forest belt around parks and scenic spots, which often has the characteristics of rich energy and material exchange. The bridge is reduced and the connectivity is reduced
Loop	A long and narrow area with corridor characteristics connecting the same core area	It represents the migration channel of energy exchange and material flow, which makes it possible to transfer and exchange in multiple core areas. Its number represents the degree of connectivity between each core area; In the ecological network, it is the channel of connection between each area. In the urban landscape, it is mostly manifested as belt green space, such as green belt, windbreak, etc. The bridge is reduced and the connectivity is reduced
Bridge	A long and narrow area with corridor characteristics in the non core area connecting multiple different core areas	The disappearance of the loop area means that the energy exchange and material flow in the region need a longer distance to reach the other end. The number of the ring area affects the aggregation degree of the patches in the core area. Reduce the number of loops and reduce their connectivity
Branch	After identifying all the landscape pixels, part of the structure is the branch line	It represents the remnant of the green landscape area that can establish contact with the core area. The results show that the maximum range of energy exchange and material flow can be reached within the green landscape pixel. The increase or decrease of branch line type has little effect on the connectivity of green landscape, and has more material and energy exchange with non green landscape

higher the fragmentation degree N_i. of the landscape, and the higher the landscape heterogeneity A. This index can describe the fragmentation of landscape types or the entire landscape (Albert et al., 2019).

Aggregation Index (AI)

$$AI = \sum_{i=1}^{n} \frac{g_i}{\max g_i} / PD. \tag{2}$$

In the formula, g_i represents the degree of plaque dispersion.

The aggregation index (AI) can map the specific patch dispersion degree within the landscape area, and its value range is between 0–100. Once the AI value is relatively small, it indicates that the corresponding dispersion is strong, otherwise it indicates that the structure is relatively compact. The degree of plaque aggregation is higher.

Dispersion Index (IJI)

$$IJI = \sum_{i=1}^{n} \frac{e_i}{\max e_i} / AI. \tag{3}$$

In the formula, e_i represents the type of plaque.

The Dispersion Index (IJI) can effectively show the types of patches and the overall dispersal and arrangement status. Once the IJI value is relatively small, it reflects that one type of plaque is only adjacent to a relatively small number of other types; $IJI = 100$ reflects that the corresponding neighboring probabilities of the plaques are almost the same (Krasnoyarova et al., 2019).

Average fractal dimension (FRAC_MN)

$$FRAC\_MN = \frac{2}{IJIp_{ij}}. \tag{4}$$

In the formula, p_{ij} represents the shape of the landscape patch.

The average fractal dimension (FRAC_MN) reflects that the corresponding shape of the landscape patch is highly complex, and its value lies in the range of 1–1.6. Once the value of the corresponding fractal dimension approaches 1, the patch shape will appear Similar to a rectangle, the disturbance caused by humans is relatively large (Liu et al., 2018).

Landscape division (DIVISION)

$$\text{DIVISION} = 1 - \sum_{j=1}^{n} FRAC\_MNp_{ij}. \tag{5}$$

Once the corresponding value is closer to 1, it reflects that the effect of the landscape divided by the relevant road is more significant.

Shape Index (LSI)

$$\text{LSI} = \frac{E}{\text{DIVISION}}. \tag{6}$$

In the formula, E represents the degree of interference.

The shape index (LSI) value can effectively reflect the change in the shape of the corresponding patch in the landscape. Once the LSI value gradually increases, the corresponding irregularity will increase. The degree of fragmentation and disturbance of the landscape in a specific area will also be directly reflected in the space environment.

Contagion Index (CONTAG)

$$\text{CONTAG} = \frac{Ep_{ij}}{\text{LSI}}. \tag{7}$$

The contagion index (CONTAG) represents the spreading trend of different patch types, which can effectively evaluate the landscape pattern to a certain extent. Once the CONTAG value is relatively low, it is further mapped that there are a lot of small patches inside the landscape, that is, the degree of fragmentation is relatively severe. Once the CONTAG value is relatively high, it reflects the highly connected patch types in the landscape (Fu et al., 2020).

Shannon Diversity Index (SHDI)

$$\text{SHDI} = \sum_{i=1}^{m} \text{CONTAG}p_{ij}. \tag{8}$$

The Shannon Diversity Index (SHDI) also reflects the spatial heterogeneity of the landscape to a certain extent, and is especially sensitive to the uneven distribution of various patch types. When the value is 0, it means that there is only one landscape patch type. An increase means that there are multiple types of plaques in the area and their distribution is more balanced.

1.3. Pattern feature extraction of urban wetland ecological landscape types

According to the selected landscape pattern index, the MSPA analysis method is used to extract the characteristics of urban wetland ecological landscape types, which mainly include: core area, patch area, ring road area and bridge area, pore area and edge area, and branch line area.

A. Core area extraction

The extraction of the core area uses the 8-neighbors algorithm, that is, if the eight neighboring pixels around the center pixel are all vegetation pixels, then this pixel is the core area pixel.

B. Extraction of plaque area

The patch area is simply an isolated island area where the foreground pixels are concentrated, that is, a collection of pixels that are not connected to other types of landscape structures. The specific acquisition principle is based on the pixel set of the core area, the expansion operation is performed, and the foreground pixels connected to the core area are selected, and the remaining isolated pixel set is the patch area (Bin & Yu, 2018).

C. Extraction from ring road area and bridge area

Using the skeleton extraction algorithm, the bands and slender domains are filtered out in batches, that is, a set of connected area type pixels is obtained. The pixel set is further classified. If the selected pixel set is connected to the same core area, it is classified as a loop type; If the selected pixel set is connected to different core areas, it is classified as a bridge area.

D. Extraction of pore area and edge area

Both the pore area and the edge area are connected to the core area. The only difference is that the pore area is inside the core area and the edge area is outside the core area. The specific acquisition principle is to first remove the pixel sets of the patch and connection area types (circle area and bridge area), and then expand a pixel set of edge width both inside and outside the core area to obtain a pixel set of edges and pores. In the interpretation of the pixel set, if it is outside the core area, it is the edge area; if it is inside the core area, it is the pore area.

E. Extraction of branch line area

After going through the above based steps, there are still some pixels remaining. This type of pixel basically has one end connected to the foreground pixel, and one end is a connected set of non-vegetation pixels. The specific acquisition step is to remove all classified pixel sets from all pixel sets, and the remaining pixel sets are branch areas.

2. Construction of ecological landscape planning model of urban wetland

Based on the above-mentioned extracted urban wetland ecological landscape pattern characteristics, the point cloud transformation method is used to construct an urban wetland ecological landscape planning model. This model is to calculate the minimum function of the three-dimensional wetland ecological landscape cloud fusion transformation, and use this function to calculate the three-dimensional translation transformation amount. The rotation matrix of the three-dimensional model and the scaling factor of the three-dimensional model transform and construct a three-dimensional model of wetland ecological landscape planning, thereby completing the construction of the wetland ecological landscape planning model (Yang et al., 2019).

Assuming that δ_1 represents the overall pattern point cloud model, and δ_2 represents the partial pattern point cloud model. The similarities between the two are $\delta_{\varphi 1}$ and $\delta_{\varphi 2}$. The minimum function calculation formula for the 3D wetland ecological landscape cloud fusion transformation is as follows:

$$S(\delta_{\varphi 1},\delta_{\varphi 2}) = \left\| \delta_{\varphi 1} - (\sigma \cdot \delta_{\varphi 2} \cdot \eta + T) \right\|. \tag{9}$$

In the formula, σ represents the three-dimensional zoom factor; η represents the rotation matrix of the three-dimensional model; T represents the amount of three-dimensional translation transformation.

According to formula (9), the specific steps of transforming the three-dimensional model of wetland ecological landscape planning by using the function sought are as follows:

(1) Three-dimensional translation transformation amount

Assuming that G represents the geometric center point of the three-dimensional wetland landscape point cloud model; R_τ represents the τ-th coordinate point in the three-dimensional wetland landscape point cloud model; O represents the number of the three-dimensional wetland landscape point cloud, and the calculation formula for the collective center point of $\delta_{\varphi 1}$ and $\delta_{\varphi 2}$ is as follows:

$$G = \sum_{\tau=1}^{O} R_\tau / O. \tag{10}$$

According to formula (10), suppose the geometric center points of $\delta_{\varphi 1}$ and $\delta_{\varphi 2}$ are G_1 and G_2, respectively, and use the coordinate normalization method to translate the geometric center point to the position of the origin G. The calculation formula of the collective translation transformation is as follows:

$$T = (G_1 - G_2) + (G - G_1). \tag{11}$$

(2) Rotation matrix of 3D model

If it is ensured that the wetland landscape point cloud model remains unchanged during conversion, the OPP algorithm is used to limit the rotation matrix. When $\det(T) = 1$, the calculation formula of the optimal rotation matrix is as follows:

$$J = ITU^{\nu}. \tag{12}$$

(3) The zoom factor of the 3D model

Let $l(\cdot)$ denote the number of traces of the matrix, and the calculation formula of the scaling factor is as follows:

$$\eta = l(JT) / \delta_{\varphi 2}. \tag{13}$$

After converting the translation transformation value, the rotation matrix value and the scaling factor, the expression of the point cloud in G_2 converted to the G_1 coordinate system is as follows:

$$G_2' = \eta \cdot G_2 \cdot J + T. \tag{14}$$

When the point cloud of the overall pattern and the point cloud of the partial pattern are fused, namely $G_1 \cup G_2$, the construction of the urban wetland ecological landscape planning model is realized.

3. Simulation experiment analysis

In order to verify the performance of the urban wetland ecological landscape planning model constructed in this paper based on the MSPA analysis method in practical applications, a simulation experiment analysis was carried out. The simulation experiment environment is shown in Table 2.

Table 2. Simulation experiment environment

Name	Parameter
Computer hardware	CPU Intel due to Core (TM) i5 – 3 230 M 2.6 UGHz, memory size 4 GB, hard disk size 1 TB
Development language	Java (Version number: 1.8.0 111)
Development tools	Eclipse (Version number: Neon.2 Release 4.6.2)
Third-party library	Weka (Version number: 3.8.1), Mulan (Version number: 1.5.0), l K-Analyzer (Version number: 5.0.1)
Operating system	Windows 10 Ultimate Edition
Other tools	U1traF.dit (Version number: 24.00.0.72), StarUML (Version number: 5.0.2.1570)

Take an urban wetland ecological landscape as the research object, obtain the experimental sample data of urban wetland ecological landscape through UAV and three-dimensional laser scanner, sort out the collected data, fill in the missing data, and take the processed data as the experimental sample data. Song et al. (2019) model and Zeng and Xu (2020) model are tested as experimental comparison models, and the application effects of different methods are tested by verifying the accuracy and planning time of urban wetland ecological landscape planning. Among them, the higher the accuracy of urban wetland ecological landscape planning, the better the planning effect. The shorter the time of urban wetland ecological landscape planning, the higher the overall planning efficiency, which can be further popularized in practice.

(1) Precision comparison of urban wetland ecological landscape planning

In order to verify the effectiveness of the method in this paper, a comparative analysis of the urban wetland ecological landscape planning accuracy of the model in this paper, the model in Song et al. study and the model in Zeng and Xu's study is carried out (Song et al., 2019; Zeng & Xu, 2020). The comparison results are shown in Figure 1.

It can be seen from Figure 1 that the urban wetland ecological landscape planning accuracy of the urban wetland ecological landscape planning model based on the MSPA analysis method constructed this time can reach up to 99%, which is higher than that of the method in Song et al. study and the method in Zeng and Xu's study is carried out (Song et al., 2019; Zeng & Xu, 2020). The high accuracy of wetland ecological landscape planning indicates that the urban wetland ecological landscape planning effect of this method is better, and the expected goal of this research has been achieved.

(2) Time comparison of urban wetland ecological landscape planning

In order to further verify the effectiveness of the model in this paper, a comparative analysis of the urban wetland ecological landscape planning time of the model in this paper, the model in Song et al. study and the model in Zeng and Xu's study is carried out (Song et al., 2019; Zeng & Xu, 2020). The comparison results are shown in Figure 2.

According to Figure 2, the urban wetland ecological landscape planning time of the model in this paper is within 36 s, the urban wetland ecological landscape planning time of the model is within 48 s (Song et al., 2019), and the urban wetland ecological landscape planning time of the model is within 46 s (Zeng & Xu, 2020). It shows that the urban wetland ecological landscape planning time of the model in this paper is shorter than that of the model in Song et al. study and the model in Zeng and Xu's study (Song et al., 2019; Zeng & Xu, 2020), and the planning efficiency is high.

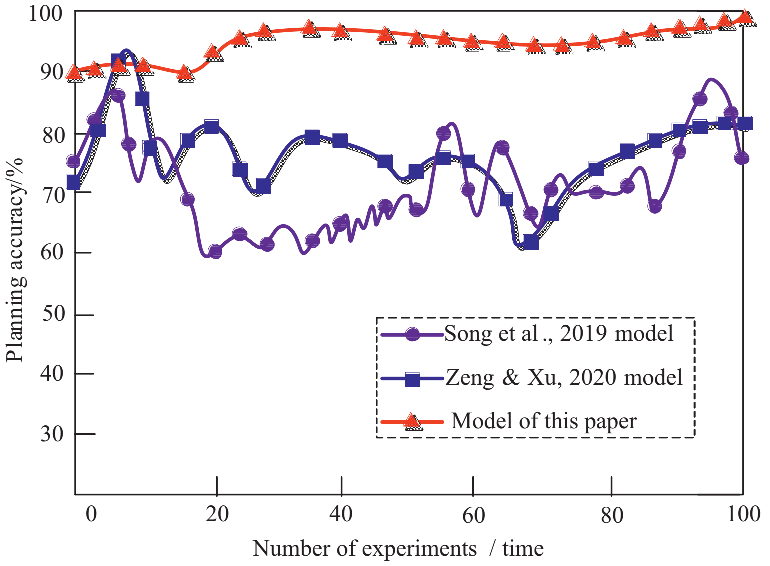

Figure 1. Comparison results of planning accuracy

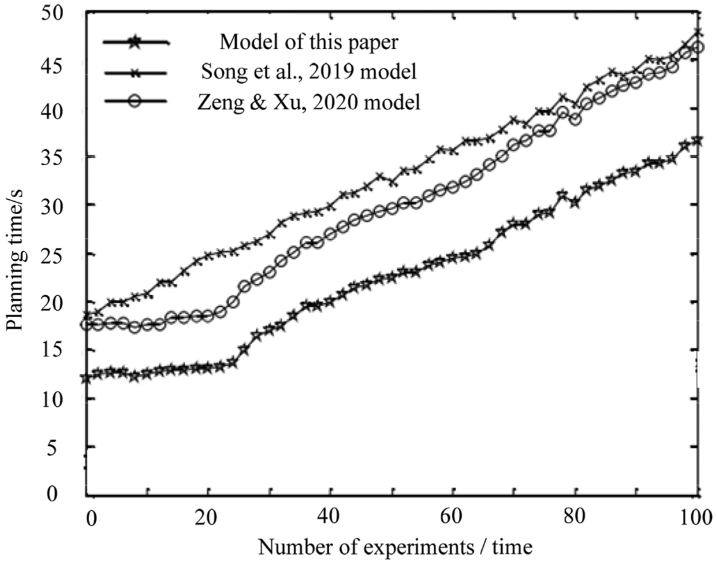

Figure 2. Comparison results of planning time

Conclusions

Urban wetland is an important part of the construction of urban ecological environment. There is a complex relationship between urban development and urban wetland construction. Urban wetland is an important urban ecological infrastructure and an important natural system for urban sustainable development. It is included in urban green spaces. Within the scope of the system planning, it has the functions of regulating the urban climate, beautifying the urban environment, replenishing groundwater, storing water and flood control, scientific research and education, and rich diversity of flora and fauna. It is also a good place for urban residents to travel. The "back garden" of the city. At present, the biological diversity of the urban artificial ecosystem is extremely lacking. Improving the biological diversity of the urban green space system has become an important task in the construction of urban green space in my country. Therefore, it is extremely important to construct an urban wetland ecological landscape planning model.

Traditional methods have the problems of low accuracy and long planning time of urban wetland ecological landscape planning, so it is of great research significance to design a new urban wetland ecological landscape planning model. In this paper, MSPA analysis method is used to construct the urban wetland ecological landscape planning model, and the simulation experiment shows that the model can improve the accuracy of urban wetland ecological landscape planning and shorten the planning time. The main contribution of this paper is to completely protect urban wetland resources, restore wetland animal and plant habitats, maintain the integrity of wetland ecosystem, improve the self circulation ability of urban wetland, give full play to the ecological benefits of urban wetland, and build an urban wetland park integrating education, tourism and leisure.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

It is declared by the authors that this article is free of conflict of interest.

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