



Construction of Eco Industrial Park Planning Model Based on Ant Colony Algorithm

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Abstract. Conventional eco industrial park planning mostly adopts methods and principles, with strong limitations, lack of comprehensive consideration of the industrial chain of the park, and poor planning effect, resulting in a high carrying rate of the eco industrial park ecosystem. Based on this, the ant colony algorithm is introduced, and the research on the construction of ecological industrial park planning model based on ant colony algorithm is proposed. First, select key industries in the park and establish the industrial chain of eco industrial park. Secondly, the ant colony algorithm is used to build a mathematical model of eco industrial park planning and determine two multi-objective indicators for eco industrial park planning. On this basis, a menu style planning and design framework is established from the three perspectives of park architecture, road traffic and ecological landscape to plan and design the ecological industrial park in an all-round way. The experimental analysis results show that after the application of the proposed planning model, the carrying rate of the park ecosystem is low, and the coordination degree between the carrying capacity of the ecosystem and the carrying capacity is high, which can promote the sustainable construction and development of the industrial ecological park.

Keywords: Ant colony algorithm · Plan · Eco industrial park · Construction · Model

1 Introduction

In a broad sense, the eco industrial park belongs to a complete system, including the subsystems of economy, environment, resources, management and other factors [1]. The eco industrial park system is similar to the material circulation system in the ecological environment, in which enterprises play the roles of “producers”, “decomposers” and “consumers” [2]. The Eco Industrial Park, which gathers a large number of eco industrial enterprises, is a practical form of circular economy and sustainable development. Its main purpose is to minimize the consumption of production energy and resources, minimize environmental pollution, and promote industrial economic development [3]. In the ecological industrial park, the establishment of a sound ecological industrial chain (network) and planning model can effectively reduce the energy and resources consumed in industrial production, and reduce the environmental pollution caused by industrial emissions, which belongs to a sustainable development model [4] to promote industrial production and operation.

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Theoretically, building an eco industrial park planning model can significantly improve the current construction level of the park. According to the planning model, it can effectively enrich the various indicator systems, and constantly adjust the standard values of indicators in combination with the real-time dynamic changes of industrial production development, so as to better guide the construction of the park and comprehensively promote the construction and development of the eco industrial park [5]. Generally, most eco industrial parks have a long construction period, a large construction scale, and many projects involved. Scientific park planning models can provide powerful help for park construction, comprehensively improve the ecological civilization environment of the park, and improve the economic efficiency of the park [6]. Ant colony algorithm, also known as ant algorithm, refers to a simulated evolutionary algorithm in a broad sense, which is mainly used to find optimization paths. This algorithm can provide strong support for the construction of the planning model of the eco industrial park [7]. Based on this, this paper introduced ant colony algorithm, combined with the construction characteristics of the park, carried out research on the construction of the planning model of the eco industrial park, and then comprehensively and multi-dimensionally reflected the drawbacks in the current park construction, timely adjusted the industrial structure, on the one hand to help improve the deficiencies and shortcomings in the park construction, on the other hand to contribute to improving the social image of the eco industrial park.

2 Construction of Planning Model of Eco Industrial Park Based on Ant Colony Algorithm

2.1 Establish the Industrial Chain of Eco Industrial Park

Before establishing the industrial chain of the eco industrial park, first select the key industries of the park. Key industries are the key nodes in the circular symbiotic industrial chain network structure, which have the characteristics of large material flow and strong linkage with other industries. The selection of key industries determines the formation and improvement of the symbiotic circular industrial chain and affects the park's industrial symbiosis function, so the determination of key industries is particularly important [8]. In combination with the above key industry selection principles, the analytic hierarchy process (AHP) is used to build a hierarchy model for the selection of key industries in the eco industrial park, as shown in Fig. 1.

As shown in Fig. 1, the hierarchy of key industries selection for the eco industrial park designed in this paper can achieve the goal of selecting key industries in specific regions. On this basis, the industrial chain of the eco industrial park [9] is extended by means of vertical extension. By combining the advantages of local industries, select key industries, design the leading industry chain around key industries, analyze the composition of various wastes and products produced by the leading industry chain, and find enterprises that can reuse them. Through such enterprises, the products and wastes produced in the leading industry chain are reused to extend the leading industry chain and achieve the purpose of full utilization of resources [10]. In the specific design of industrial chain extension, we should not blindly extend the industrial chain, but ignore

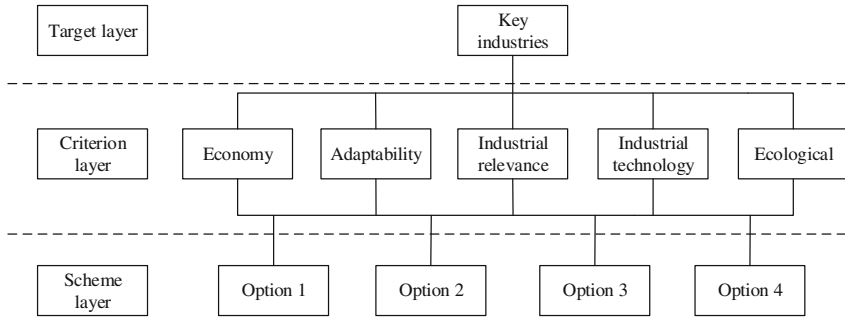


Fig. 1. Hierarchical structure model of key industries selection in eco industrial parks.

the feasibility and operability of the current ecological industrial technology, resulting in a waste of resources [11]. According to the established hierarchical model of key industry selection in the park, the alternative industries of the eco industrial park are designed, as shown in Table 1.

As shown in Table 1, it is an alternative industry for the industrial chain of the eco industrial park. On this basis, in order to achieve the goals of economic growth, environmental improvement and industrial ecological transformation within the region, on the basis of vertical extension and horizontal coupling, it will cooperate with other enterprises, parks and residents within the region to exchange waste and products; Realize the exchange and sharing of regional information, technology, knowledge and infrastructure; Form a circular symbiotic industrial chain network [12] that is mutually beneficial with the natural environment and artificial environment. Finally, the recycling and efficient utilization of materials and energy and the minimization of pollution emissions within the region will be realized to drive regional economic development and improve the ecological environment [13].

Table 1. Alternative Industry Design of Eco industrial Park Industrial Chain

No	Industry
1	Electronic information industry
2	New material industry
3	Biomedical industry
4	Automobile industry
5	Chemical industry
6	Power transmission and transformation equipment industry

2.2 Building Mathematical Model of Park Planning Based on Ant Colony Algorithm

After completing the establishment of the industrial chain of the eco industrial park, the association between the various industrial structures in the park was clarified. Next, the ant colony algorithm was used to build a mathematical model for the planning of the eco industrial park, providing a basic guarantee for the subsequent planning and design of the park.

Similar to bionic algorithms such as genetic algorithm and artificial neural network, ant colony algorithm is a new bionic optimization algorithm, mainly derived from the foraging behavior of real ant colonies, and is a heuristic optimization algorithm [13]. Ants can always find the shortest path for foraging in groups. At present, ant colony algorithm has been successfully applied in traveling salesman problem, job scheduling and other problems [14]. Due to its distributed positive feedback parallel computer system, it is easy to combine with other methods, and has strong robustness. It is suitable for the site selection and planning of eco industrial parks [15]. There is information transmission between ant colonies, and the transmission medium is a substance called pheromone. Each ant will release this pheromone in the process of foraging and save it on the path. Other ants will find this path according to the pheromone [16]. Because pheromones have a certain volatility, the longer the ants search for food, the less pheromones remain on this path, and on the contrary, the more pheromones remain on the path. If the number of ants passing through the path is more, then the pheromone concentration will also increase, and the probability of being selected by other ants is greater, until all ants are attracted to gather on the same path, then the path is the shortest path [16].

First, put m Only ants are randomly placed in different sub parks in the eco industrial park, initializing the amount of information on each side of the industrial park $\tau_{ij}(0) = C$. Search the tabu list according to the ant colony algorithm, and calculate the transfer probability of ants from the current sub park to all sub parks that have not been there $p_{ij}^t(t)$, the calculation expression is:

$$p_{ij}^t(t) = \begin{cases} \frac{\tau_{ij}^\alpha(t) \cdot \eta_{ij}^\beta(t)}{\sum \tau_{is}^\alpha(t) \cdot \eta_{is}^\beta(t)}, j \in n \\ 0 \end{cases} \quad (1)$$

Among them, α represent information heuristic factors, that is, the role of pheromones accumulated in the path in path selection; β represents the expected value heuristic factor, that is, the role of the heuristic factor in path selection; $\tau_{ij}(t)$, $\tau_{is}(t)$ express t the amount of information remaining between sub parks at any time; $\eta_{ij}(t)$, $\eta_{is}(t)$ express t at any moment, the degree of expectation of the transfer from a sub park to another sub park. After ants visit all sub parks of the EIP, update the information on each path, and the calculation expression is:

$$\tau_{ij}(t+n) = (1-\rho) \cdot \tau_{ij}(t) + \Delta\tau_{ij} \quad (2)$$

Among them, ρ represents the mean value of volatilization degree of all pheromones on the path; $\Delta\tau_{ij}$ indicates the total amount of information retained by ants in this path

cycle. On this basis, initialize the parameters and cycle parameters in the ant colony algorithm for eco industrial park planning, set the number of algorithm cycles, enter the park path planning cycle, update the search taboo table, write the location of each ant's starting park into the search taboo table, and select the sub park with the highest transfer probability to visit [16]. If the number of elements in the search tabu table is less than m , repeat the above steps; If the search taboo table is full, it means that the ants have visited all the sub parks in the park, saved the ants' crawling paths, and calculated the sum of the paths taken by the ants, which is the shortest path planned for the eco industrial park.

On this basis, the mathematical model of park planning is constructed. Due to the restrictions of land resources, cash flow, inventory turnover period and other factors within the eco industrial park, there are certain choices between the number of selected industries and the number of selected enterprises. We can build industries and enterprises in stages to avoid excessive pressure on the operation of the whole park, which will lead to excessive leverage risk. Therefore, in order to restrain the operational leverage risk caused by the rapid development of enterprises. As a result of the above analysis, the constraints of the park planning mathematical model are designed as shown below.

$$\sum_i^m x_i \leq M \quad (3)$$

Among them, M indicates the number of industrial chains planned for the eco industrial park; x_i indicates the number of industries under construction at the same time. Based on the constraints of model construction and the emphasis on economic, environmental and social benefits of traditional industrial parks, this paper focuses on the application of ecological industrial economic theory, clean industry theory, circular economy theory, etc. Combining the actual situation of the eco industrial park's own industrial planning, such as the geographical location, the strategic direction of the park's development, upstream and downstream enterprises, etc., comprehensively consider the functions and positioning of the park's industrial planning, and stimulate the endogenous power. Considering the development of the economic benefits of the enterprises in the park in the macroeconomic cycle and the planning analysis of the future industry, the two multi-objective indicators of the planning mathematical model of the ecological industrial park are finally determined: the initial economic growth demand and the later endogenous power demand. To sum up, the mathematical model of eco industrial park planning based on ant colony algorithm is completed.

2.3 Planning and Design of Ecological Industrial Park

After the above mathematical model of eco industrial park planning based on ant colony algorithm is constructed, the eco industrial park is planned and designed on this basis. The planning idea and framework of the eco industrial park designed in this paper are shown in Fig. 2.

As shown in Fig. 2, this paper focuses on the planning and design of the park buildings, road traffic, ecological landscape and infrastructure of the park to form an ecological industrial park planning. What is built is a menu style planning and design framework. Eco industrial parks in different regions and types can choose corresponding paths and

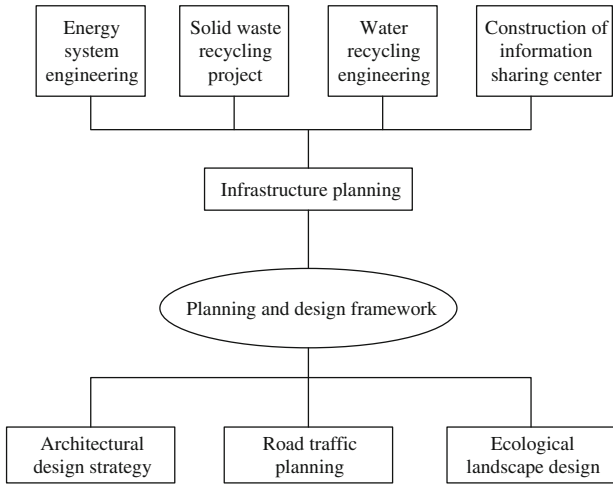


Fig. 2. Planning idea and framework of eco industrial park

methods according to their own resource characteristics and needs within this framework. But for the overall planning idea, it basically follows the general direction from architectural design, road traffic planning, ecological landscape design to infrastructure planning. The specific planning and design are as follows.

1. Architectural planning and design of ecological industrial park. At the beginning of planning and layout, such buildings should be arranged in the downwind of prevailing wind in the area where the industrial park is located to avoid pollution or impact on the living area of the park. On this basis, the location of industrial buildings shall be determined based on the production process functions of various enterprises: industrial buildings with special process production requirements shall be designed specifically. For example, if some processes are not suitable for natural light, it is necessary to reduce the use of artificial light sources in building design; If it is necessary to maintain good indoor ventilation, the building groups and indoor doors and windows shall be arranged reasonably; For buildings with various requirements such as temperature, humidity, sterility, etc., corresponding measures should be taken in terms of building plane, structure and air conditioning. The external landscape can also be introduced into the interior of industrial buildings through design techniques to improve the internal environment of industrial buildings and improve the quality of employees' working environment.
2. Road traffic planning and design of ecological industrial park. In terms of travel time, the peak traffic of the park staff is concentrated on commuting, while the time for tourists to enter the park is relatively random. In terms of travel mode, most employees living in the park mainly use walking and cycling due to the proximity of their living places to their working places. If they want to leave the park, they will mainly use public transportation and cycling. For employees living outside the park, they can choose their travel modes according to the distance between their residence and the park. Among them, bus, car, bicycle and walking are all possible travel modes. For

tourists, most of them travel by car. In the specific practice of eco industrial parks, most of the districts are divided according to the traffic function needs of the parks, and most of them adopt mixed road network structures. Generally, the chessboard road network is used in the production area, while the free road network is used in the living area. The combination of the two can not only meet the traffic efficiency requirements of the industrial park, but also better highlight the humanization and ecological characteristics of the ecological industrial park. The road grade shall be designed according to the grade design idea of “main road secondary main road branch road”. In the practice of specific ecological industrial park, the road grade shall be designed according to the short-term and long-term planning, scale and specific traffic volume of the park. It shall not be designed as a three-level road blindly and rigidly to avoid waste of resources. The design of road cross section shall be based on the road class and functional requirements. Road cross section can generally be divided into four forms: single width double lane, double width multi lane, three width multi lane and four width multi lane. The width of small vehicle lane is generally 3.5m; The width of mixed driving lane and large vehicle lane is generally 3.75m; The width of tricycle lane is 2m; The width of bicycle lane is generally 1m; The width of side road strip is generally 5 ~ 7.5m, including the width of sidewalk, street trees and facility strip; The width of the dividing strip is generally 1m.

3. Ecological landscape planning and design of ecological industrial park. The landscape nodes of the eco industrial park generally exist in the form of single buildings, theme sculptures, pavilions, green clusters, etc., which are the highlights of the park's landscape. It is mainly distributed in areas with concentrated flow of people and good natural landscape conditions. In the specific design, we can build a variety of landscape nodes with different styles according to the actual situation of different functional areas of the park, such as production area, living area and storage area. At the same time, the humanistic and artistic characteristics of landscape nodes should also be realized through the use of various design techniques, such as landscape penetration, deconstruction, and combination of reality and emptiness. The introduction of four ecological landscape elements, namely rainwater garden, permeable pavement, concave green space and green planting, can further highlight the ecological and environmental characteristics of the park, so as to achieve the unity of the park's landscape functionality and ecology.

3 Experimental Analysis

3.1 Experiment Preparation

The R ecological industrial park in a certain region is selected as the target of this study. It is located in an important economic functional area of the region, including the bonded area, economic zone and logistics zone. The overall planning area is about 76.1851 square kilometers, which is jointly approved by the Ministry of Environmental Protection, the Ministry of Science and Technology and the Ministry of Commerce. After years of development and accumulation, the eco industrial park has gathered more than 140 investment projects from Fortune 500 enterprises, forming six major industrial clusters. Under the guidance of the leading group, the construction of the ecological

industrial demonstration park in the park has steadily progressed. R Eco industrial Park takes the opportunity of promoting the development of ecological industry, carries out the construction of industrial chain, establishes the environmental protection reverse force mechanism, and drives the industrial upgrading of the park; Implement infrastructure construction and improve ecological and livable environment; Promote the efficient use and sharing of resources and energy, and constantly improve the level of environmental management and services. The total population of the park is 580000, including 310000 registered population. In the process of urbanization, a large number of rural population has transferred to urban population, and the influx of population from other places has increased the regional population density rapidly. The population density of some cities and towns exceeds 1000 people/km². The park is dominated by manufacturing industry, and the proportion of the first, second and third industries is 0.3:82.5:17.2.

The regional climate of R Ecological Industrial Park belongs to monsoon marine climate, with four distinct seasons and a long frost free period of about 240 days. The atmospheric environmental conditions in the industrial park are general, and most of the primary pollutants are total suspended particles. It is mainly affected by fuel combustion, fugitive dust from construction sites, motor vehicle exhaust and other factors. The daily average values of total suspended particles, sulfur dioxide, nitrogen dioxide and carbon monoxide in the park are lower than the secondary standard of GB 3095–96. In terms of long-term development trend, carbon monoxide gradually shows a downward trend, and other indicators are basically flat, of which sulfur dioxide has an upward trend. From the perspective of water environment, the water pollution of all rivers in R Eco industrial Park is relatively serious, and the water quality is poor. The main items exceeding the standard are permanganate index, TP, petroleum, etc. Therefore, the comprehensive improvement of river water environment should be strengthened in the park planning. After mastering the general information of R Eco industrial Park, according to the above discussion, the planning model of eco industrial park is constructed, and the planning application effect of the model is comprehensively tested.

3.2 Result Analysis

Considering the actual situation and characteristics of R eco industrial park, the ecological system carrying rate of the industrial park is selected as the evaluation index for this planning experiment. Applying this evaluation index to evaluate the carrying capacity of the ecosystem of the industrial park can intuitively obtain the deviation between the current situation of the ecological environment of the industrial park and the target value, and get whether the ecosystem of the park is beyond the carrying range. The carrying capacity of the industrial park ecosystem is related to the structure of the ecosystem itself, the input and output of the outside world (human social and economic activities). For eco industrial parks, most external inputs are industrial production. If in this experiment, the ecological system carrying capacity of the industrial park EBC as a function, it contains the following variables: Time T , Space S Human behavior activities B , the function expression is:

$$EBC = f(T, S, B) \quad (4)$$

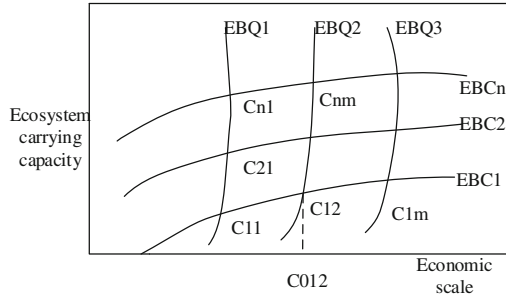


Fig. 3. Schematic diagram of changes in ecosystem carrying capacity and ecosystem carrying capacity with economic scale

Among them, in the ecological scope of the industrial park, the carrying capacity of the ecosystem will change under different levels of economic activities and different environmental protection inputs. Ecosystem carrying capacity and ecosystem carrying capacity EBQ the graph of changes with economic scale is shown in Fig. 3.

In Fig. 3, three curves $EBC1$, $EBC2$, $EBCn$ respectively represents the corresponding carrying capacity of the park ecosystem under different environmental protection input levels; curve $EBQ1$, $EBQ2$, $EBQn$ the corresponding carrying capacity of the park ecosystem under different economic behavior directions; $C012$ indicates the optimal economic scale corresponding to the balance point of ecosystem carrying capacity and carrying capacity. On this basis, calculate the ecological system carrying rate of the eco industrial park, and the formula is:

$$EBR = \sum_{i=1}^n W_i \cdot \frac{EBQi}{EBCi} \quad (5)$$

When the carrying rate of the industrial park ecosystem is greater than 1, it means that the carrying capacity of the park ecosystem exceeds the carrying capacity range, which may cause serious environmental problems in the park, which is not conducive to the construction and development of the park; The smaller the carrying rate, the higher the coordination degree between the carrying capacity of the entire industrial park ecosystem and the carrying capacity of the ecosystem, and the better the overall planning effect. In order to make the experimental results more intuitive, comparative analysis method is used to set the above ecological industrial park planning model based on ant colony algorithm as the experimental group, and the park planning models proposed in literature [1] and literature [4] as control group A and control group B respectively for comparative analysis. Select 6 sub parks in R Eco industrial Park, use the above three methods to plan the 6 sub parks, use simulation analysis software, measure and calculate the carrying rate of the 6 sub parks after planning, and draw a comparison chart as shown in Fig. 4.

In Fig. 4, 01 represents the civil aerospace sub park; 02 stands for equipment manufacturing sub park; 03 stands for biomedicine sub park; 04 stands for FMCG sub park; 05 stands for information and communication sub park; 06 stands for modern service sub park. The comparison results in Fig. 4 show that the above three planning models for eco industrial parks have different planning effects after application. Among them,

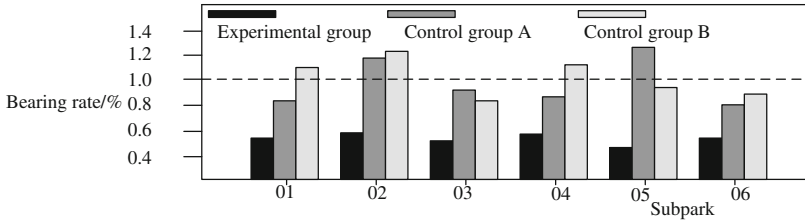


Fig. 4. Comparison Results of Ecological System Bearing Ratio in the Park

after the application of the park planning model based on ant colony algorithm proposed in this paper, the carrying rate of the six sub park ecosystems is below 1, and is significantly smaller than the other two methods; The control group A proposed that after the application of the model, the carrying rate of the ecosystem of two sub parks exceeded 1, and there was an overload problem; The control group B proposed that after the application of the model, the carrying rate of the ecosystem of three sub parks exceeded 1, causing serious overloading problems. It is easy to see from the comparison results that the planning model of eco industrial parks based on ant colony algorithm proposed in this paper has a high application advantage. After the park is planned, the coordination degree between the ecological system carrying capacity and the ecological system carrying capacity is high, which can promote the efficient use and sharing of ecological resources and energy in the park.

4 Conclusion

The construction of eco industrial parks plays an important role in promoting environmental protection and ecological economy. In order to promote the healthy development of eco industrial parks, it is very important to build the planning model of eco industrial parks. Based on this, this paper introduces ant colony algorithm to design the construction method of the planning model of industrial ecological park. Through the research in this paper, the carrying rate of the park's ecosystem has been effectively improved, the coordination between the park's ecosystem carrying capacity and the ecosystem carrying capacity has reached a higher level, the industrial layout of the eco industrial park has been optimized, and it has important research significance for improving the park's ecological civilization environment.

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