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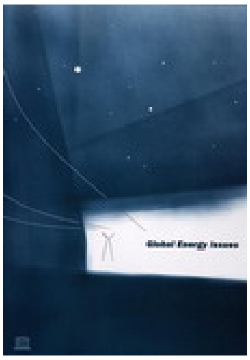

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The green building benefit grading evaluation based on improved FPA algorithm

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Abstract: In order to solve the problem of low recall rate and accuracy of traditional methods, a green building benefit grading and evaluation method based on improved FPA algorithm was proposed. Firstly, the index system of green building benefit grading and evaluation is constructed, and the economic incremental benefit, social incremental benefit and environmental incremental benefit of green building are calculated according to the index system. Then, based on the incremental benefit calculation results, the green building benefit grading evaluation function is constructed. Finally, the improved FPA algorithm is used to optimise the objective function, so as to obtain the optimal solution and complete the green building benefit grading evaluation. The experimental results show that the evaluation results of economic, social and environmental benefits of the proposed method are consistent with the actual situation. The highest recall rate is 95%, and the average accuracy is 93%.

Keywords: improved FPA algorithm; economic benefit; social benefit; environmental benefit; evaluation index system; objective function; benefit evaluation.

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1 Introduction

At present, the development of green building has been widely concerned and valued by the country and society, and has been gradually promoted and applied. As an important component of sustainable development, the implementation of high efficiency and energy saving is an inevitable requirement for the development of green building (Liang et al., 2019; Rao et al., 2019). At present, green building has developed to a certain level. However, due to the difference in information communication between the builders and the beneficiaries, the development of green building is limited to some extent, and the relationship between the influences of all parties cannot be well balanced. For promoting the development of green building, need to establish an effective evaluation index, to evaluate benefit of green building classification, according to the evaluation results improve the benefit of green building, provide more reference basis for development in this field, so the green building efficiency grading evaluation method has important research significance (Jin, 2017).

The relevant scholars at home and abroad have made in-depth studies on the benefit evaluation of green building, and obtained some research results. Tian (2020) put forward a kind of green building performance evaluation method based on the index weighting method, this method in order to ensure that green building design method is scientific, for green building design method was improved, green building design standard, uses the theory of ecological optimisation design method of the index weighting method, in order to design for green building three-tier system model of performance evaluation. However, the accuracy of this method is not high. Alsulaili et al. (2019) put forward a kind of green building performance evaluation method based on the questionnaire survey, the method application of the green building concept, environmental and economic benefits analysis to assess the influence of the traditional buildings, and clarifies the residents awareness of green building concept, use Google form designed a questionnaire, according to the results of questionnaire survey design the green building performance evaluation system, the system is used to get the final evaluation results, but this method has the problem of low recall rate, and the practical application effect is not good. Ye et al. (2019) put forward a green building benefit evaluation method based on multi-dimensional evaluation, this method first benefit of green building multidimensional evaluation index is established, and then build 'benefits-production' model, finally using the model for the benefit of green building and evaluation, in order to get more precise green building performance evaluation results, but the imperfection of the index system building, causes the evaluation accuracy to decrease. Wang (2019) put forward a kind of green building performance evaluation method based on BIM technology, the method based on green building theoretical basis, from the perspective of the costs and benefits to the analysis of the green building efficiency factors, environmental benefit and increment benefit as the main content is analysed, using BIM technology research and the green building environmental benefits, but the result of the evaluation of the building benefit is not accurate enough.

Traditional method is easy to fall into local optimum in the process of calculation, thus lead to economic benefit, social benefit and environmental benefit assessment results and actual situation has a large gap, the recall rate and low accuracy, this paper in order to solve the problems existing in the traditional method as the research target, design a kind of green building based on FPA algorithm efficiency grading evaluation method. Therefore, the evaluation results of economic benefits, social benefits and environmental benefits of this method are closer to the actual situation, and the recall rate and accuracy are high, which can lay a foundation for the related research of green building. The overall technical route of the method is as follows:

1 From the economic benefit, social benefit and environmental benefit analysis in three aspects: the influence factors of green building benefit and will benefit the three data as the original data, constructing evaluation index system of green building economic benefit, on the basis of the index system of green building of economic increment incremental benefits, social incremental benefits and environmental benefits.

2 Based on the calculation results of incremental benefits, the green building benefits grading evaluation function was constructed, and the improved FPA algorithm was used to optimise the objective function, so as to obtain the optimal solution and complete the green building benefits grading evaluation.

3 The gap between the evaluation results of economic benefit, social benefit and environmental benefit of the method in this paper and the actual situation was verified through experiments, and the recall rate and accuracy of different methods were compared.

2 Construction of green building benefit evaluation index system

In recent years, green building has attracted great attention from the state. Green building can effectively alleviate environmental pollution and resource consumption, and greatly reduce the utilisation rate of resources, thus alleviating environmental pollution (Zhao et al., 2017). In the process of promoting green building, the benefit of green building is an important index to measure and develop level. Its essence is to realise the economic value, environmental value and social value of building through green technology. Therefore, the benefits of green building can be divided into three main parts: economic benefits, social benefits and environmental benefits.

Economic benefit is a kind of explicit benefit, mainly through energy saving and material saving direct economic effect; Social benefits are mainly reflected in the impact on people's living environment and quality of life, which is a kind of implicit benefit (Chen and Wang, 2018). Environmental benefits are mainly reflected in both indoor and outdoor levels, through the impact of green building on indoor environmental quality and its improvement, such as air cleanliness and noise impact (Wang et al., 2020).

Green building projects are complicated to a certain extent, with numerous influencing factors and diverse evaluation indicators. Therefore, it is impossible to use simple and single indicators for project evaluation. Instead, it is necessary to adopt evaluation indicators for systematic evaluation of green buildings and construct an evaluation index system for green building benefits (Li and Li, 2017). Economic benefit, social benefit and environmental benefit are taken as the original data to construct the green building benefit evaluation index system on this basis. The results are shown in Table 1.

Table 1 Evaluation index system of green building benefit

	First level indicators	*Secondary indicators*
Evaluation index of green building benefit	Economic benefits	Energy-saving benefits
		Water-saving benefits
		Benefit of saving
		Land-saving benefits
	Social effect results benefit	Supporting facilities for residents
		Efficiency
	Environmental benefit	Sewage
		Health benefits
		Building life

3 Grading and measurement of incremental benefits of green buildings

Compared with benchmark buildings, the increased economic, social and environmental benefits of green buildings are called incremental benefits (Dwaikat and Ali, 2018). Based on the construction of the evaluation index system, the incremental economic benefit, social benefit and environmental benefit of green building are respectively measured. The specific measurement methods are as follows:

3.1 Incremental economic benefits

According to the evaluation index system of green building in Table 1, the calculation of economic incremental benefits should be mainly analysed from four aspects of energy saving, water saving, material saving and land saving (Adele and Carlos, 2017).

Implementation of energy-saving benefit mainly through energy saving material, energy-saving equipment and the use of energy-saving measures to achieve energy-saving bride price including building palisade structure, new type energy saving energy, energy saving equipment including some advanced technology and equipment and the new type energy saving system, etc., energy-saving measures by technology and project management to achieve (Xiao et al., 2017). In short, the ultimate generation of energy-saving benefits of green buildings is reflected by the amount of energy saved. The calculation formula is as follows:

$$E = (Q_2 - Q_1) \times P_e \tag{1}$$

In the above formula, Q_2 represents green buildings use energy, Q_1 represents energy for reference buildings, P_e represents energy unit (Niu et al., 2017).

Water saving is an important strategic component of water resources management in green buildings. Compared with benchmark buildings, green buildings usually adopt more advanced technical means in the construction process, such as water resource recycling and water-saving equipment, to achieve water saving. The calculation formula is as follows:

$$W = (w_2 - w_1) \times P_w \tag{2}$$

In the above formula, w_2 represents water consumption in green buildings, w_1 represents water consumption for reference buildings, P_w represents water unit.

Building construction process, material consumption and waste are very concern a problem, but the green building will adopt a more reasonable design scheme and operation means, as far as possible, reduce material consumption, it will also take the technology of recycling residual construction material, garbage sorting and recycling use, etc., to reduce resource waste (Xuan et al., 2017).

The calculation formula of building material saving is as follows:

$$M = (m_i P_i + m_j P_j + m_k P_k) \times \beta \tag{3}$$

In the above formula, m_i, m_j and m_k represent the saving of different types of building materials in the process of green building construction, including high performance materials, new materials and recycled materials, P_i, P_j and P_k represent the unit price corresponding to the three types of building materials, β represents weight adjustment parameters (Ding et al., 2021).

The land-saving benefit of green building mainly lies in improving the efficiency of land use and saving land resources through the design of schemes and the application of technologies, such as the design of underground garage. The calculation formula of land saving benefit is as follows:

$$L = P_l \sum_{i=1} (d_i) \times \alpha \tag{4}$$

In the above formula, d_i represents land saving of influencing factors i, α represents weight factors for different types of land-saving modes, P_l represents land unit (Mi et al., 2019).

3.2 Incremental social benefits

Incremental social benefit is a hidden benefit. Green building can provide leisure and entertainment places for residents, plan reasonable energy utilisation programs, and improve residents' quality of life. Meanwhile, relevant studies show that green buildings can improve the air quality of the surrounding environment and improve people's work efficiency (Shao et al., 2019). Therefore, the incremental social benefits are mainly reflected in the healthy and comfortable living environment provided by green buildings and the improvement of people's work efficiency.

3.3 Incremental environmental benefits

Green building construction pays attention to the greening treatment of resources, such as the reutilisation of rainwater and the reduction of sewage discharge, so as to reduce pollutant discharge (Chen and Zhou, 2020). The calculation formula is as follows:

$$S = \Delta R \times P_s \tag{5}$$

In the above formula, ΔR represents reduced sewage emissions from green buildings, P_s represents sewage treatment unit.

Similarly, the reduction of exhaust emissions will also bring some incremental environmental benefits. Green building construction will reduce the use of fossil fuels, reduce exhaust emissions and effectively alleviate air pollution. The calculation formula of emission reduction benefit is as follows:

$$G = \Delta T \times P_g \tag{6}$$

In the above formula, ΔT represents reduced emissions from green buildings, P_g represents unit price for waste gas treatment.

Green buildings can effectively reduce environmental pollution and improve air quality, thus affecting the indoor and outdoor environment, creating a good environment for people's life, reducing the occurrence of respiratory diseases and improving people's health. Therefore, health benefits are also part of the incremental environmental benefits (Macnaughton et al., 2019), and the calculation formula is as follows:

$$C = X\left(\varnothing_2 - \varnothing_1\right) \times F \tag{7}$$

In the above formula, X represents environmental regulation index, $\varnothing_2$ and $\varnothing_1$ represent environmental composite indices for green and benchmark buildings, F represents medical expenses.

In addition to pollutant emission and health benefits, the extension of building life can also reflect the environmental benefits of green buildings (Piers et al., 2018). Relevant studies show that the quality of air will directly affect the corrosion rate of building materials. The calculation formula of building life benefits is as follows:

$$J = \delta\left(\varnothing_2 - \varnothing_1\right) \tag{8}$$

In the above formula, δ represents environmental quality regulation parameters.

Based on the above formula, the overall calculation results of incremental environmental benefits of green buildings are obtained as follows:

$$A = \lambda\left(S + G + C + J\right) \tag{9}$$

In the above formula, λ represents accommodation coefficient.

4 Benefit evaluation of green building based on improved FPA algorithm

4.1 Improve FPA algorithm

FPA algorithm is a meta-heuristic swarm intelligent optimisation algorithm. Compared with other optimal solution algorithms, FPA algorithm has significant advantages such as fewer parameters and strong flexibility, and performs well for all kinds of problems. However, in real life, many optimal problem solving processes have strong complexity, so it is necessary to improve the FPA algorithm to adapt to more practical applications.

Conventional FPA algorithm using random initialisation more pollen position, easy to produce pollen position the problem of insufficient ergodicity, prompted a certain deviation, the calculation results to solve this problem, this article selects the genetic algorithm to improve the FPA, by using the genetic algorithm in high ergodicity of chaotic sequence characteristics make up for a lack of regular FPA algorithm. Therefore, the diversity of the population can be guaranteed and the accuracy of the calculation results can be improved.

The biological cross-pollination of FPA algorithm can be regarded as a global search process, which can be expressed as:

$$x_i^{l+1} = x_i^l + \eta L(x) \times f \tag{10}$$

In the above formula, x_i^l and x_i^{l+1} represent the l and $l+1$ iteration values of particles, respectively, $L(x)$ represents the step length, η represents a step-length influence factor, f represents the current optimal position.

Abiotic cross-pollination of FPA algorithm can be regarded as a local search process, which is expressed as:

$$x_i^{l+1} = x_i^l + \eta L(x) \times \left(1 - x_i^l\right) \tag{11}$$

According to the above analysis, it can be seen that the update of the FPA algorithm is mainly based on the iteration of pollen particles, so with the infinite increase of the number of iterations, the problem of local optimal solution cannot be solved. As a result, this paper introduces the problem of chaotic sequence improvement in genetic algorithm, takes the optimal solution obtained at this time as the initial value, constructs the mapping function to update the population, and obtains the new optimal solution. The improved FPA algorithm mapping formula is as follows:

$$x_{ik} = min_k \left(x_i^{l+1} - x_i^l\right) + (1+)\eta \times \left(1 - H(k)\right) \frac{\left(max_k - min_k\right)}{2} \tag{12}$$

In the above formula, x_{ik} represents the *k* coordinate map of the *i* particle after iteration, min_k represents the *k* dimensional minimum in the particle pollination search space, max_k represents the *k* dimension maximum in the particle pollination search space, $H(k)$ represents the original value of *k* dimensional coordinates.

Through chaotic sequence mapping operation, the shortcoming of FPA algorithm can be improved, the diversity of population can be improved, the computing ability can be enhanced, and the more accurate optimal value can be obtained.

4.2 Realisation of green building benefit classification assessment

FPA algorithm has less parameters, can improve the flexibility and other significant features, for the calculation of all kinds of effects are better and applicability, and other advantages, so in this paper, based on the improved algorithm of FPA three levels from the economic, social and environmental quantitative analysis of the green building incremental benefits, build costs and benefits of multi-objective functions. The improved FPA algorithm is used to optimise the objective function, obtain the optimal solution, and complete the green building benefit grading evaluation.

The economic, social and environmental benefits generated by each technology are summarised to obtain the annual incremental benefits, and the annual benefit value is discounted to obtain the maximum present value of the incremental benefits. The calculation formula is as follows:

$$\max B = A\sum_{a}\sum_{b}U_{ab}t_{a}t_{ab} \times Z\left(\Delta\theta, m, \tau\right) \tag{13}$$

In the above formula, t_a represents the duration of a technology, t_{ab} represents the b option for the use of the a technology, U_{ab} represents the benefits of a technology, $Z\left(\Delta\theta, m, \tau\right)$ represents the discount factor for incremental benefits, $\Delta\theta$ represents annual incremental benefits, m represents calculation period, τ represents rate of return.

The minimum incremental cost is calculated by the following formula:

$$\min \mathrm{V} = \sum_{a}\sum_{b}V_{ab}t_{a}t_{ab} + O \tag{14}$$

In the above formula, V_{ab} represents costs arising from technology a, O represents basic costs.

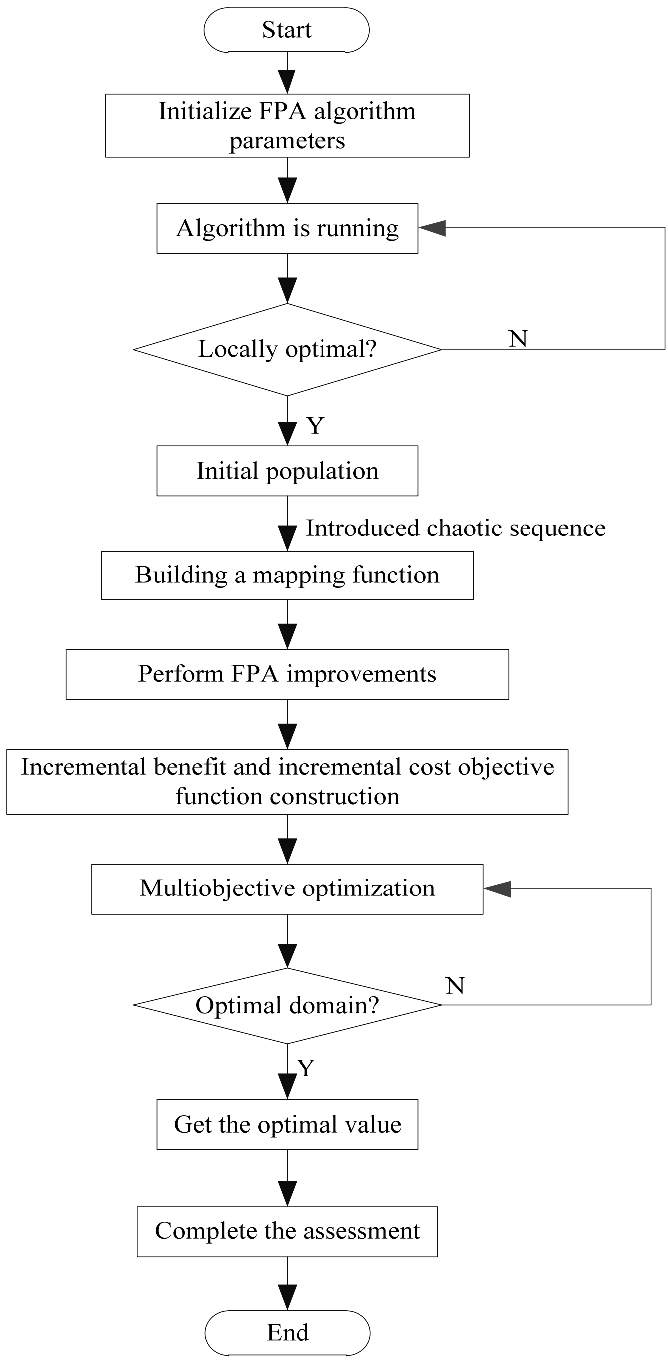
According to the calculation results of maximum incremental benefit and minimum incremental cost, the green building benefit grading evaluation function can be constructed, and the improved FPA algorithm can be used to calculate the optimal solution of the objective function:

$$\max \mathrm{D} = \frac{J_1\left(B, V\right)}{J_2\left(B, V\right)} \tag{15}$$

In the above formula, $J_1\left(B, V\right)$ represents the incremental benefits in the optimal solution domain, $J_2\left(B, V\right)$ represents the incremental cost in the optimal solution domain.

According to the above calculation, the optimal grading evaluation value of green building benefits can be obtained, and the evaluation study based on the improved FPA algorithm can be completed. The specific green building benefit grading evaluation process is shown in Figure 1.

Figure 1 Green building benefit grading assessment process



5 Experimental analysis

5.1 Experimental scheme

In order to verify the effectiveness of the green building benefit grading evaluation method designed in this paper, experiments are designed to verify the performance of the proposed method. The overall experimental scheme is as follows:

1 *Experimental environment*: The experimental operating environment is shown in Table 2.

2 *Experimental data*: The green building project in a certain area was selected as the research object, and all the data of the project were taken as the experimental sample data to improve the accuracy of the simulation experiment.

3 *Experimental evaluation method*: The Tian (2020) method, Alsulaili et al. (2019) method, Ye et al. (2019) method and Wang (2019) method as experiment contrast method. First of all, the presented approach are verified through the experiment of economic benefit, social benefit and environmental benefit assessment results and the actual situation of the gap, and the actual gap is smaller, the closer the benefit evaluation results and the actual.

Table 2 Experimental operation environment

Runtime environment	*Configuration*	*Parameter*
Hardware environment	CPU	Intel(R)Core(TM)i5-9400
	Frequency	2.90 GHz
	RAM	16.0 GB
Software environment	Operating system	Windows 10
	Version	18362.1082 pro
	Digits	64 bit
	Analogue software language	APDL
	Simulation software	Matlab 7.0

On this basis, recall rates of different methods are compared, which refers to the number of positive examples in all data samples that are correctly predicted. The calculation formula of this index is as follows:

$$recall = \frac{TP}{TN + FN} \tag{16}$$

In the above formula, TP represents the number of positive categories predicted into positive categories, TN represents the number of negative categories predicted into negative categories, and FN represents the number of positive categories predicted into negative categories.

Then, the evaluation accuracy of different methods is calculated by the following formula:

$$ACC = \frac{TP + TN}{TP + TN + FP + FN} \tag{17}$$

In the above formula, *FP* represents the number of negative classes predicted to be positive classes.

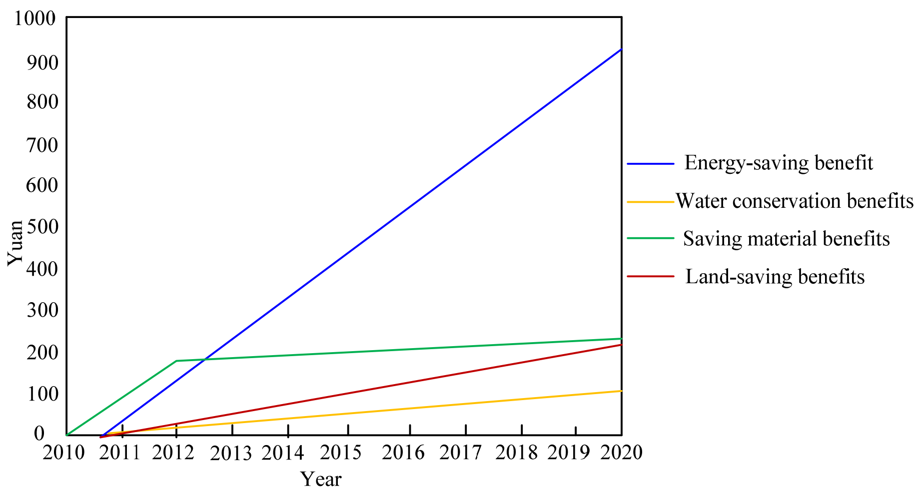
5.2 Analysis of experimental results

5.2.1 Actual application effect

1 *Economic benefit simulation analysis*

According to the content of the text, the economic benefit evaluation effect of green building can be reflected by simulating the benefits of energy saving, water saving, material saving and land saving. Based on the economic benefit of green building from 2010 to 2020, the economic benefit curve of green building project is shown in Figure 2.

Figure 2 Economic benefit curve of green building project

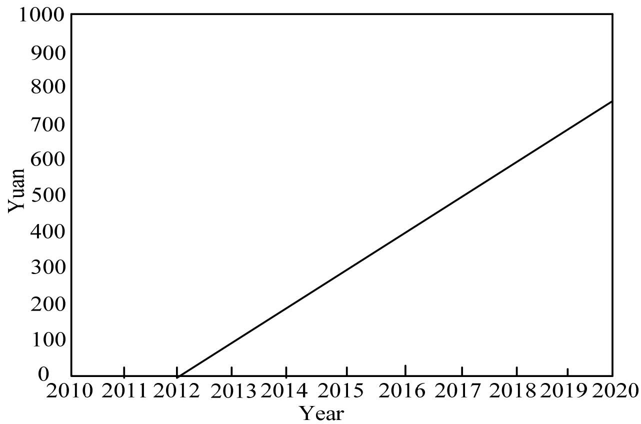


Analysis of Figure 2 shows that green building project economic efficiency curve can be obtained, energy saving, water saving benefits and section to benefit all have certain delayed, during the period of green building project has just gone into construction, the project can only have certain benefits to save material, on the aspects of energy-saving, water-saving and land benefit is no significant improvement. With the progress of the project, the economic benefits of green building in saving energy, water resources and land use have been gradually accumulated after the trial operation and operation phase. On the contrary, the material saving benefit is only reflected in the construction stage of the project. After the completion of the project, there is no need to use materials, and the material saving benefit reaches the maximum and no longer increases. It can be seen from the above economic benefit analysis process that the simulated results obtained by using the benefit evaluation method in this paper are consistent with the actual results, which indicates the correctness of the evaluation method in this paper.

2 *Simulation analysis of social benefits*

The quantitative simulation of social benefits is mainly reflected by the improvement of residents' income level. The social benefit curve of green building projects is shown in Figure 3.

Figure 3 Social benefit curve of green building project

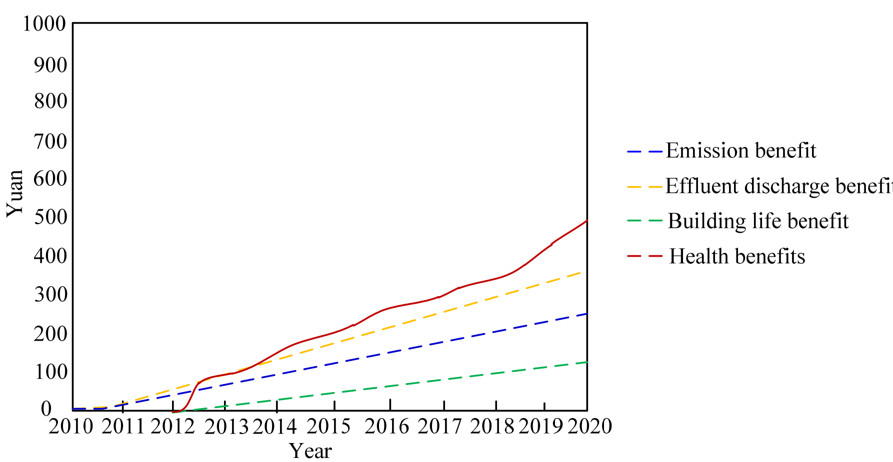


According to the curve simulation results of residents' economic income in Figure 3, green buildings have a positive impact on the increase of residents' economic income. Social benefits cannot be generated at the initial stage of the project. Social benefits begin to be generated after residents move in after the completion of the project.

3 *Simulation analysis of environmental benefits*

Environmental benefits are mainly reflected in the aspects of waste water discharge, waste gas emission, health benefits and green building life. The environmental benefit curve of green building projects is shown in Figure 4.

Figure 4 Environmental benefit curve of green building project



According to the curve changes in Figure 4, it can be seen that the emission benefits of waste gas and waste water are less and not obvious in the initial construction stage of the project. After the project is put into use in the later stage, the emission benefits of waste gas and waste water gradually increase. Building life benefit and health benefit are also in the same trend. The use of green building materials reduces the damage to the building itself, and at the same time reduces the incidence of respiratory diseases of residents, which gradually increases the life benefit and health benefit of the building. According to the curve trend, the evaluation method in this paper is consistent with the actual situation, which further verifies the effectiveness of the method in this paper.

5.2.2 Comparison of recall rates

The recall rate of the evaluation method was used as the index to compare and analyse the method of this paper with Tian (2020) method, Alsulaili et al. (2019) method, Ye et al. (2019) method and Wang (2019) method, and the recall rate ratio was made, as shown in Table 3.

Table 3 Comparison results of recall rates of different assessment methods (%)

Number of experiment	*Method of this paper*	*Tian (2020) method*	*Alsulaili et al. (2019) method*	*Ye et al. (2019) method*	*Wang (2019) method*
10	92	87	76	69	60
20	93	88	80	68	63
30	93	83	85	70	65
40	94	86	86	69	66
50	95	89	87	71	68

In 50 times of simulation analysis, the recall rate of green building benefit evaluation by this method is more than 90%, the highest is 95%, while other literature research methods are not more than 90%, the gap is obvious. According to the evaluation criteria, the higher the recall rate is, the better the algorithm performance is. This is because this paper analyses and considers the economic, social and environmental benefits of green building in detail, and obtains a more accurate comprehensive benefit evaluation result of green building, which improves the recall rate of this evaluation method.

5.2.3 Accuracy analysis of evaluation methods

The optimal value of green construction benefit objective function is calculated by computer simulation, and the accuracy of different methods is calculated, which is compared with other literature methods.

Table 4 Accuracy comparison results of different evaluation methods

Number of experiment	*Method of this paper*	*Tian (2020) method*	*Alsulaili et al. (2019) method*	*Ye et al. (2019) method*	*Wang (2019) method*
10	91	82	72	60	60
20	92	79	81	61	65
30	93	78	83	63	65
40	93	80	85	62	66
50	96	86	85	66	64

It can be seen from the analysis of Table 4 that the method in this paper has a good accuracy, the average accuracy is as high as 93%, the Tian (2020) method is relatively high, but the maximum accuracy is not more than 86%, the Alsulaili et al. (2019) method is as high as 85%, the accuracy of the Ye et al. (2019) method and Wang (2019) method is relatively low, the maximum accuracy is 66%. Compared with the method in this paper, there is a big difference. The main reason for this result is that the FPA algorithm was improved in this paper, which effectively avoided the situation that the algorithm solution was caught in the local optimal situation, increased the accuracy rate of the calculation of the objective evaluation function, thus improved the overall accuracy rate of the algorithm, and provided new data and theoretical support for the green building benefit evaluation.

6 Conclusions

1. The analysis of green building benefits is the necessary direction and key content of the development of the construction industry. Aiming at the problem that the existing building benefit evaluation methods are easy to fall into the local optimal solution and cannot accurately obtain the benefit evaluation results, this paper proposes a new green building benefit grading evaluation method based on the improved FPA algorithm.
2. The experimental results show that the evaluation results of the economic benefit, social benefit and environmental benefit of the proposed method are consistent with the actual situation, and the recall rate of the proposed method is up to 95%, and the average accuracy is up to 93%. Therefore, the method has the characteristics of high recall rate and evaluation accuracy.
3. However, in this paper, the benefit of green building assessment method research also has certain insufficiency, in the process of establishing evaluation index system, mainly to consider factors that can determine, for the exploration of some hidden factors remains to be further analysis, at the same time, the simulation results of parameters in the simulation process of in-depth analysis, cannot fully reflect the green building evaluation results.
4. In the future research will further explore the influencing factors, and build a richer, more comprehensive evaluation index system, at the same time, the key may be produced in the process of analysis and calculation parameters, and the influence of related parameters on the assessment results, in order to improve the performance of evaluation methods, provide more basis for the development of the green building industry.

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