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Cost Control Model and Algorithm of Green Building (Intelligent Building) Construction Project Oriented to Sustainable Development

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Abstract The Building Industry (BI) has developed rapidly. Today, to satisfy the needs of current social development, the BI has begun to rise a wave of green buildings. However, at this stage, the building form of green building has not been widely popularized. The reason is that the construction cost has been high to a large extent, which is also the biggest obstacle to the development of the Green Building Industry (GBI). Therefore, how to adopt effective methods to reduce the construction cost of green buildings and promote the vigorous development of the GBI has become the most important problem facing the development of the GBI. Based on the problem of high construction cost encountered by the GBI at this stage, the ant colony algorithm and distributed clustering algorithm were adopted to reduce the construction cost to the maximum extent and promote the healthy development of the GBI under the premise of ensuring the construction quality from multiple perspectives by building a digital model. By comparing the data obtained from the traditional construction method and the construction method using the ant colony algorithm and the distributed clustering algorithm, it can be seen that the material cost of the same type of building was reduced by 9.7% and the energy use was saved by 30.3% after using the ant colony algorithm and the distributed clustering algorithm. Compared with traditional building forms, green buildings had a better user experience. The cost of garbage recovery of green buildings using ant colony algorithm has been reduced by 27.3%. Compared with traditional buildings, green buildings had absolute advantages in terms of energy conservation, environmental protection and user experience. Therefore, how to better apply the two algorithms to the BI and promote the transformation of the BI to the green BI has important guiding significance.

Index Terms Sustainable Development, Green Smart Buildings, Project Construction Costs, Models and Algorithms

I. Introduction

At present, the concept of Sustainable Development (SD) has been effectively popularized throughout the society. The BI has followed the development needs of the times and started to pursue more efficient, more energy-saving and less polluting construction methods. Since entering the new century, people have realized the importance of energy conservation, emission reduction and environmental protection. The development of the BI needs to consume a lot of energy. At the same time, the BI is also the major culprit of environmental pollution. How to reduce the energy use in the BI and reduce the impact of the BI on environmental pollution has become a problem that has to be solved in the current development process of the BI. In view of the drawbacks existing in the BI at this stage, the concept of green building came into being. Green building relies on scientific and reasonable planning, and has the characteristics of low energy consumption and low environmental pollution. It has become the direction and goal of the development of the BI at present, but the current high cost of GBI has become the biggest obstacle to the development of green building. Therefore, how to reduce the construction cost of green buildings has become an urgent problem for the GBI. In view of the problem of high cost in the development of green buildings at this stage, this paper applies ant colony algorithm and distributed clustering algorithm to green buildings. Through scientific and reasonable planning of the management mode of the whole construction project, selection of building materials, design style and other aspects, it aims to reduce the construction cost of green buildings, promote the development of green industry, provide ideas for the transformation of traditional BI, and also promote the SD of the BI.

Many practitioners and relevant researchers in the BI have mentioned the problems of high energy consumption and environmental pollution in the BI and put forward solutions in green buildings. Yan Shengpeng pointed out that the BI would produce a large amount of construction waste during the construction process. The traditional way to deal with construction waste is mainly to accumulate and burn, which has caused serious pollution to the air and land. In the green BI, this problem can be effectively solved by establishing a garbage recovery mechanism and recycling waste construction materials [1]. Wibowo Mochamad Agung said that the production of building materials in the BI was accompanied by the consumption of a large amount of energy, including oil resources, water resources, etc. In the construction process, most of the building materials were not effectively utilized, resulting in waste, and would also cause pollution to the environment, forming a vicious circle. Therefore, it is necessary to find more energy-saving and more environmentally friendly building materials to replace the existing building materials [2]. Shurrab Jaber said that traditional buildings would also cause harm to human health in subsequent use, such as a large amount of dust and harmful gases generated during decoration, while green buildings can effectively reduce the harm of dust and harmful gases to human body by accelerating the air flow in the buildings through scientific and reasonable design of ventilation [3].

The above researchers mentioned the advantages of green buildings compared with traditional buildings, including the selection of building materials, the recycling and treatment of construction waste, the use of energy, air pollution and human injury. However, at this stage, green buildings have not been widely popularized. The reason is that the construction cost of green buildings is too high, and how to reduce the construction cost of green buildings and promote the healthy development of the BI has become an urgent problem for the current BI [4].

In view of the problem of high construction cost of green buildings, this paper proposes two solutions, namely, ant colony algorithm and distributed clustering algorithm. The two methods have their own characteristics. The ant colony algorithm has more advantages in material selection and cost, while the distributed clustering algorithm is unique in management mode. Both methods can effectively solve the current problem of high construction cost of green buildings. The application of the two methods would provide important theoretical support for the transformation of traditional BI to green buildings and promote the SD of green buildings.

II. Significance of Developing Green Buildings and Cost Control Methods

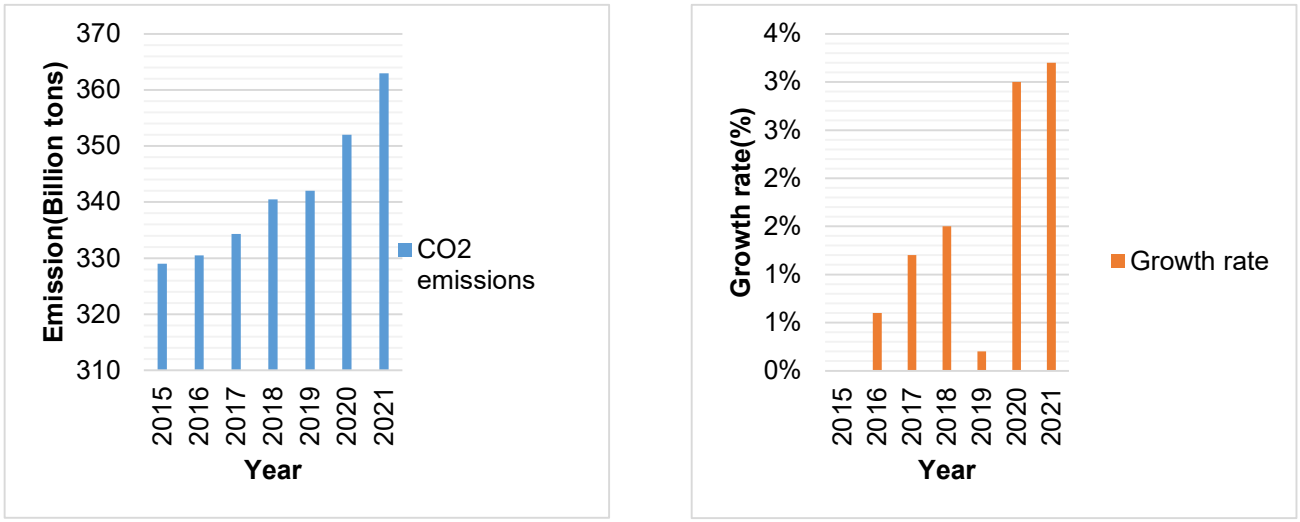
II. A. Significance of Developing Green Buildings

In the course of human development, in the more than 200 years since the industrial revolution, the practice of human development at the expense of the environment seems to be more harmful than beneficial [5]. A new wind vane of energy conservation and emission reduction has emerged in all walks of life, and the concept of SD has been implemented. In this era, the BI should also seize the opportunity to promote the BI to develop towards green building, so as to achieve the healthy development of the entire BI.

In the long run, vigorously developing green buildings can save resources and reduce carbon dioxide emissions [6]. In terms of current technology, the traditional BI has greatly increased the carbon dioxide emissions in the selection of construction materials and construction process. Now, because of the pollution of some enterprises, human activities and environmental damage, the carbon dioxide content in the atmosphere has increased, exacerbating the problem of global warming, as shown in Figure 1. Among them, Figure (a) is the schematic diagram of global carbon dioxide emissions in recent years, and Figure (b) is the schematic diagram of the growth rate of global carbon dioxide emissions:

As can be seen from Figure 1, since the 21st century, the global carbon dioxide emissions have increased day by day, and the global carbon dioxide emissions have reached more than 30 billion tons per year. From the carbon dioxide emissions, it can be seen that the environmental pollution problem has become more and more serious, which has brought many abnormal weather phenomena. These problems are caused by the damage to the environment. The traditional BI is a big polluter of the environment, including the traditional BI, which uses a lot of energy and water resources in the construction process. Because the whole process is cumbersome and redundant and there is no corresponding management model, a lot of resources would be wasted in the process. Table 1 shows the main sources of pollutants in the traditional BI:

It can be seen from Table 1 that the traditional BI is the main culprit of environmental pollution. In recent years, haze has frequently occurred in various places. This is because there is a large amount of dust (particles with particle size less than 2.5 microns) in the air. The dust in the BI mainly includes silicon dioxide, calcium oxide and other substances. In the construction process of the traditional BI, the dust on the ground, under the force of the wind, drifted into the air, resulting in this serious air pollution site. The reason why so much dust was generated is that in the construction process of the traditional BI, no attention was paid to environmental protection.



(a) (b)

Figure 1: Total global CO2 emissions and growth rates

Table 1: The main source of pollutants in the traditional BI

Major sources of pollutants		
dust	Indoor air pollution	Construction waste
A large amount of dust caused during construction	Including domestic water and construction water	Including garbage and discarded materials

The emergence of green buildings would greatly improve this situation. From the selection of materials, green buildings would pay special attention to the protection of the environment, including the selection of raw materials with less impact on the environment, and the pretreatment of some materials with certain pollution. In terms of energy use, green buildings make full use of solar energy and wind energy. Through sophisticated design, the air flow in the buildings is smooth, so as to purify the air and reduce the use of air conditioning, and save energy from another perspective.

Green buildings can reduce the generation of construction waste and promote harmonious coexistence between people and nature. A large amount of data shows that the traditional BI would produce a large amount of construction waste during the construction process [7]. The sources of these construction waste are multifaceted and the number is increasing year by year. Figure 2 shows the sources of construction waste and its annual growth rate:

The total amount of these construction wastes accounts for about 40% of the urban garbage, mainly including masonry, concrete, wood, metal, etc. According to the data obtained from the survey, the construction materials consume a lot of resources in the production process, and the construction wastes are generated largely because they are not used well, and cannot be effectively recycled. This would form a vicious circle, which is very undesirable [8]. These wastes not only occupy space, but also are the main source of fugitive dust, causing air pollution and serious damage to the environment. Most of these construction wastes are recyclable resources. If there is no good plan to recycle and dispose of these construction wastes, it would bring problems to environmental protection and resource conservation. The building materials used for green buildings would be carefully selected in the planning stage before construction, and the building materials with less environmental pollution would be the main ones. By establishing a complete recycling mechanism, some unavoidable waste caused by the construction process can be recycled. In daily life, paper and waste water are also fully recycled.

Green buildings can eliminate indoor air pollution and improve the overall comfort of the living environment. The traditional BI would produce a large number of pollutants in the construction process and subsequent decoration and use, as shown in Table 2:

It can be seen from the table that the traditional BI has produced a lot of pollutants in many aspects, including dust pollution in the construction process and subsequent decoration process. During the decoration process, the use of a large amount of paint would make the formaldehyde content in the air exceed the standard, which would not only cause air pollution, but also cause great harm to human health. At this stage, most of the households in

traditional buildings use gas and so on. However, it is inevitable that gas leakage would occur in the long-term use, which not only pollutes the living environment, but also poses a threat to personal safety and property safety to a certain extent. These risks have been taken into account before the construction of green buildings, so these hazards have been eliminated since the selection of building materials before the construction. Green buildings often use safe and harmless building materials, and deal with wood and other materials containing certain pollutants in advance. They are different from traditional buildings in architectural form. Green buildings are more scientific in design form. For example, in terms of indoor ventilation design, the ventilation of green buildings is more perfect. This design style can greatly speed up the indoor air flow, make the dust, residual gas emitted during the use of gas appliances and other gases discharged from the room faster, make the indoor air more fresh, and effectively protect the health of users.

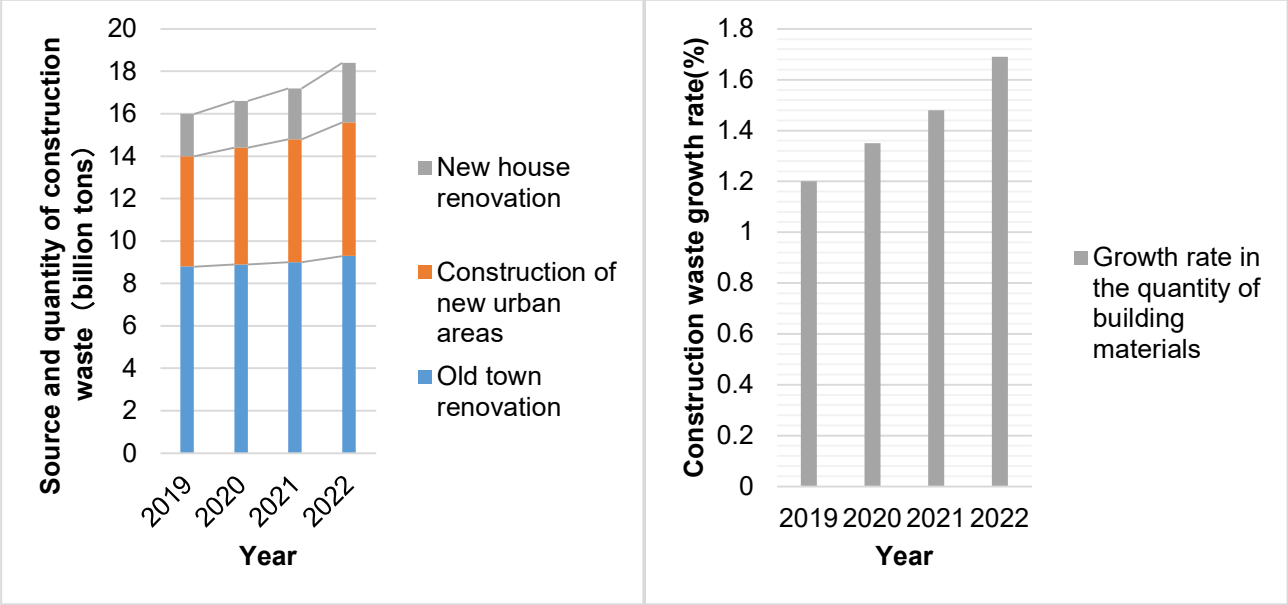


Figure 2: Source of building materials and growth rate in recent years

Table 2: A major source of pollutants in construction

Sources of air pollutants in buildings		
Dust	Formaldehyde, etc	coal gas
Dust generated during construction and renovation	Decoration materials contain a lot of formaldehyde	There is a risk of leakage of gas at any time during use

Through the introduction of green buildings and the comparison with traditional buildings, it can be concluded that green buildings are the development direction of the future BI, and green buildings have the characteristics of saving energy and improving residential satisfaction. Green buildings conform to the current concept of SD, but at the present stage, green buildings also have shortcomings [9]. From the current technical level, although they have great advantages in environmental protection and SD, GBI costs are high, and enterprises are profit-oriented. High GBI costs would lead to lower profits of enterprises. Therefore, a set of new technologies and algorithms are needed to plan the whole GBI to achieve the goal of reducing construction costs. Only in this way can green buildings develop for a long time. On this basis, finding the optimal cost solution through ant colony algorithm can solve a series of cost prediction and simulation of green buildings from the initial planning stage to the end of the project, reduce the uncertainties during the construction period, and minimize the cost through ant colony algorithm to improve profits.

II. B.Ant Colony Algorithm

Ants, as social animals, pay attention to mutual cooperation in the process of foraging. Through the observation of the process of foraging, people can find a particularly interesting phenomenon. When an ant finds food and notifies other ants, in the process of moving food, people can see that the ants are basically walking along the nearest route to the food. At this stage, many researchers have found that the fundamental reason why ants do this is that

they secrete a pheromone chemical through long-term observation of ants [10]. Each ant would secrete pheromones during walking. When more and more ants find the shortest route, the pheromones secreted by the ants on the shortest route would also be more and more, and then the ants can find the shortest route through the strong pheromones left by their companions, as shown in Figure 3:

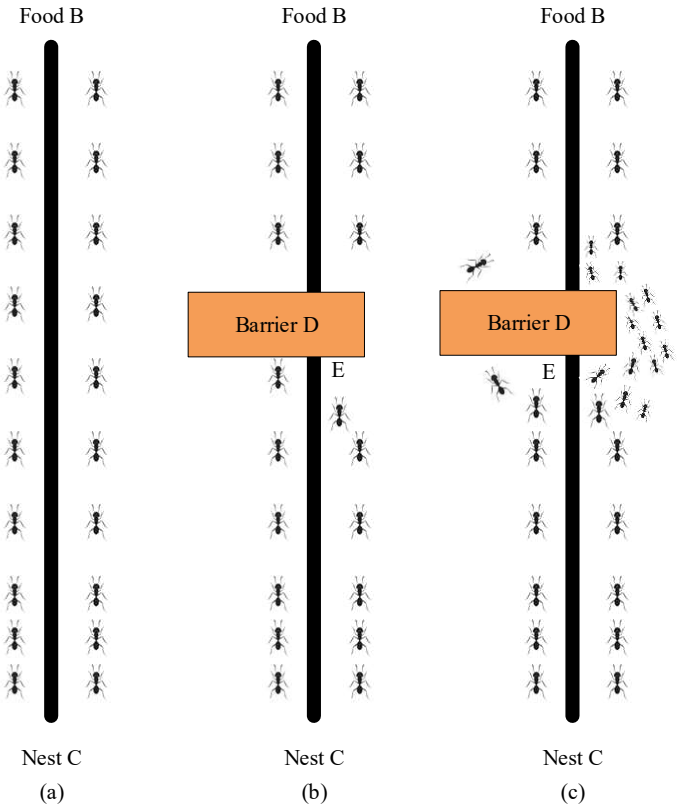


Figure 3: Conceptual map of ant colony algorithm

In Figure 3 (a), there is a group of ants. It is assumed that C represents ant nest and B represents food. This group of ants would travel along the straight path between the nest and the food. It is assumed that there is an obstacle D (as shown in Figure 3 (b)) on the straight path between ant nest C and food B. At this time, the ant at point E would make a decision. Because no ants have found food before, there is no pheromone left by the ants on the road between the food and the ant nest. Therefore, the probability of the ants walking left and right is equal. However, when an ant passes by, it would release pheromones on its way, and this pheromone would be released at a certain rate. Pheromone is one of the tools for communication between ants. The ants behind it make decisions through the concentration of pheromones on the road. It is obvious that the pheromone along the path of the short side would become more and more dense (as shown in Figure 3 (c)), thus attracting more and more ants to drive along this path.

II. C.Distributed Clustering Algorithm

Distributed clustering algorithm is an algorithm that classifies data according to their different characteristics, and stores and processes them locally [11]. When the distributed clustering algorithm classifies the data, it would divide the similar data into a single group, and the data of different groups would be relatively different. The unique classification method of the distributed clustering algorithm for data is handy in processing a large amount of data. In addition, the distributed clustering algorithm can get rid of the restriction of network speed, and is particularly fast and efficient in terms of data processing speed and algorithm execution efficiency. At the same time, it can also avoid problems such as privacy disclosure after data is accumulated together.

III. Application of Ant Colony Algorithm and Distributed Clustering Algorithm in Green Building Cost Control

III. A. Two Algorithms to Build Digital Models to Achieve the Effect of Building Cost Control

Before studying how to reduce the construction cost of green buildings, people need to understand what causes the high cost. The construction cost includes many aspects, including energy consumption cost, transportation cost, construction waste treatment cost, domestic waste treatment cost and other aspects [12]. Figure 4 shows the proportion of construction costs in the BI.

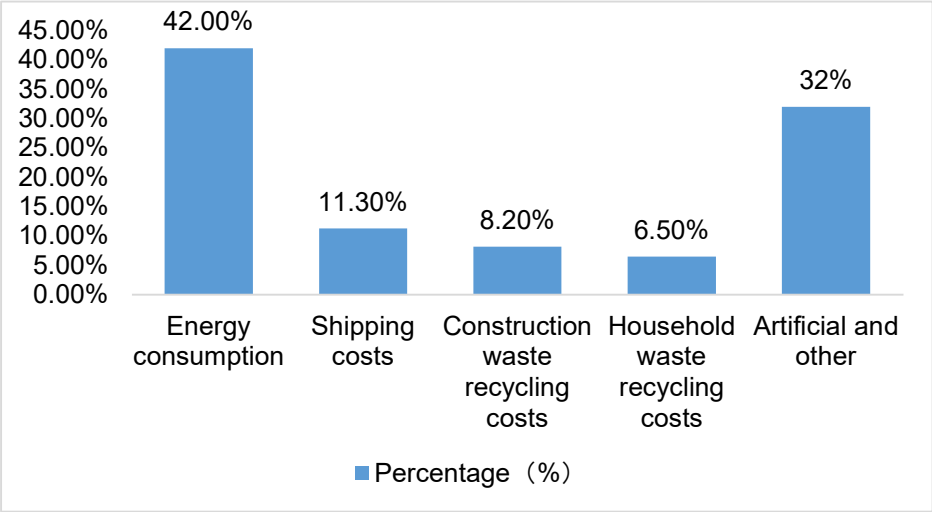


Figure 4: Chart of the proportion of cost consumption

It can be seen from Figure 4 that in the BI, energy consumption and labor and other costs accounted for 74% of the total construction cost. Energy consumption accounted for 42%; labor and others accounted for 32%; transportation costs accounted for 11.3%; the cost of construction waste recycling and domestic waste recycling accounted for 8.2% and 6.5% respectively. It can be seen that there are many elements of construction cost. At this stage, due to the chaotic management, the waste of resources has been caused in the process of construction, resulting in high cost. Therefore, how to formulate an effective management mode has become the key to reduce the construction cost.

According to the strategy of ant colony algorithm to seek the optimization method and the principle of distributed clustering algorithm to sort the data, this paper, based on these two algorithms and combined with the actual situation of the building in the construction process, estimates the cost of the building in the construction process. Thus, the problem of high cost caused by management confusion and waste can be solved, which greatly reduces the construction cost and is conducive to the development of green buildings.

Energy consumption accounts for the largest part of the construction cost, including the energy consumption in the construction project, the energy consumption in the production of building materials, etc. The energy consumption is related to the total construction amount and the construction method. The size of the construction project determines the size of the energy consumption [13]. In the process, the advantages and disadvantages of different technologies also have a deep impact on the energy consumption. The expression of energy consumption is:

$$M = \sum_{Y=1}^{O} D\mathrm{q} \times Rq \tag{1}$$

In Formula (1), M represents the energy consumption; Y represents the construction method; D represents the construction method. Through the above energy consumption formula, it can be concluded that the energy consumption formula in the transportation cost during the whole project period is:

$$M = \sum\nolimits_{O} \beta\mathrm{o} \times Uo \times C \tag{2}$$

In Formula (2), β represents the weight of building materials; U represents the transportation distance of building materials; C represents the amount of energy consumed by the transportation of building materials per

unit mass per kilometer; *O* represents the type of building materials. According to the formula, the total amount of energy consumed by raw materials and other types of transportation tasks during the construction work can be obtained. After the construction is completed and put into use, a large amount of construction waste needs to be treated. At this stage, in addition to partial recycling, most of the construction waste is treated by landfilling or stacking in the open air. Recycling and landfilling all require a certain cost. The formula of construction waste recycling cost is shown as follows:

$$M = R \times \alpha \tag{3}$$

In Formula (3), M represents the recovery cost of construction waste; R represents the amount of all construction waste generated during the construction period of the project; α represents the treatment cost of construction waste. With the development of relevant technologies and the enhancement of environmental awareness, in the treatment of domestic waste, most of them can achieve recycling and pollution-free treatment through waste classification and centralized treatment. Therefore, the cost of domestic waste treatment is different from the accumulation and landfill of construction waste. There is a new algorithm:

$$M = R \times D + \sum_{a}^{S} \times Dc \tag{4}$$

In Formula (4), *M* represents the treatment cost of domestic waste; *R* represents the total amount of domestic waste generated after the construction is completed and put into use; *D* represents the treatment cost of unit waste; Sa represents the amount of different waste processed by different technologies; Dc represents the cost required by different treatment methods. The cost of domestic waste mainly includes two aspects. One is the treatment cost of recycling and reuse, and the other is the cost of pollution-free treatment. Although both treatment methods have achieved good results at the present stage, the overall situation still requires efforts in details.

III. B. Specific Application of Ant Colony Algorithm in GBI

The experimental data in this paper comes from the field survey of a certain construction project. Then, through the model designed based on the ant colony algorithm and the distributed clustering algorithm, the simulation output data is shown in Table 3 and Table 4.

The actual application of the ant colony algorithm in GBI:

(1) In energy management optimization, the study uses the ant colony algorithm to optimize the operation of the building energy system, and adjusts the operation strategies of heating, ventilation, air conditioning and other equipment to reduce energy consumption and operating costs. Design energy management strategies in multi-energy systems, such as the integrated utilization of solar energy, wind energy and geothermal energy, and optimize the matching degree of energy production and consumption through the ant colony algorithm to improve the energy efficiency of the system.

(2) In the optimization of building material selection, the study uses the ant colony algorithm for multi-factor optimization, considering the cost, environmental impact and sustainability of the materials, and selects the best building materials to reduce the overall construction cost and optimize the environmental impact.

(3) In the optimization of the construction process, the ant colony algorithm is used to optimize the resource allocation and scheduling in the construction process, such as the management of human resources and materials, to reduce costs and improve construction efficiency. Optimize the strategy of construction waste treatment, and optimize waste classification, resource recovery and reuse through the ant colony algorithm to reduce treatment costs and environmental impact.

Ant colony algorithm is actually an algorithm for finding the optimal solution. In essence, it is inspired by the method of finding the shortest route between food and ant colony through the exchange of pheromones between the natural ant colony when searching and carrying food. By designing a complete set of integrated management models, from the early stage of the project construction, the overall planning of the whole project is achieved from the selection of raw materials, the study of detailed costs and the cost management in the subsequent use process [14]. Through the cost prediction method in the designed ant colony algorithm, the cost is reduced to the maximum extent under the premise of ensuring the construction quality, which is used to solve the problem of high construction cost in the GBI at this stage. Through the intervention of the ant colony algorithm, the GBI is promoted to reach the stage of SD, making contributions to environmental protection and energy conservation, and guiding the direction of the reform of the traditional BI. The following is a comparison between the project cost of a construction project using the ant colony algorithm management mode and the cost of a traditional construction project. The comparison is made in three aspects: the cost of materials, the cost of construction waste treatment

and the cost of energy consumption, highlighting the advantages of the ant colony algorithm in the cost of the project, as shown in Table 3:

Table 3: Cost comparison table

Unit:million(RMB)	Construction cost after using ant colony algorithm	Traditional construction costs	Reduction magnitude
Material costs	2216	2452	9.7%
Garbage disposal costs	120	165	27.3%
Energy consumption costs	92	132	30.3%

It can be seen from the data in Table 3 that the construction cost using the ant colony algorithm management mode was about 9.7% lower than the traditional construction cost in terms of material cost, 27.3% lower in terms of waste treatment and 30.3% lower in terms of energy consumption. From the cost comparison of the above three aspects, it can be seen that the cost of the whole project has been significantly reduced after the use of the ant colony algorithm management mode, and the green buildings built using the ant colony algorithm management mode had great advantages in environmental protection and other aspects. Therefore, it can be concluded that ant colony algorithm plays an important role in the cost vacancy of the GBI. With the help of ant colony algorithm, the construction cost of the GBI has been greatly reduced.

III. C. Application of Distributed Clustering Algorithm in GBI

Distributed clustering algorithm is an algorithm that classifies a large amount of data according to its characteristics [15]. In view of the chaotic management and construction in the current BI, which leads to high costs, the adoption of distributed clustering algorithm would greatly reduce unnecessary consumption and achieve the purpose of reducing costs. Table 4 shows the construction efficiency and cost of a construction site after the adoption of distributed clustering algorithm.

Table 4: The cost of a construction site

	The cost of traditional methods	Cost after using distributed clustering
Labor costs(RMB)	1110 million	912 million
Manage costs(RMB)	240 million	195 million
Construction time(days)	185	152

It can be seen from the data in Table 4 that after the adoption of the distributed clustering algorithm, in terms of human cost, the cost of the distributed clustering algorithm has been reduced by about 17.8%, and the management cost has been reduced by about 18.75%. The construction efficiency has been improved by 17.83%. The construction method using distributed clustering algorithm is more advantageous than the traditional method in terms of both cost and construction efficiency.

Practical application cases of distributed clustering algorithms in GBI:

(1) In building energy consumption monitoring and optimization, the distributed clustering algorithm is used to conduct real-time monitoring and cluster analysis of building energy consumption data, identify abnormal energy consumption patterns, adjust energy management strategies in a timely manner, and improve energy utilization efficiency.

(2) In building environment monitoring and control, the distributed clustering algorithm is used to cluster indoor and outdoor air quality data, identify pollution sources and pollution patterns, optimize ventilation and air purification systems, and improve indoor air quality.

(3) In building life cycle management, the distributed clustering algorithm is used to cluster the large amount of operational data generated by the building during its life cycle, identify problems and optimization points in operation, and improve the operational efficiency and sustainability of the building.

IV. Summary

By adopting the management mode of ant colony algorithm, the overall planning of the whole project was carried out, and the previous redundant management mode was changed, which greatly reduced the construction cost of the whole project. The actual data showed that the cost of raw materials was reduced by 9.7%; the cost of garbage recovery and treatment was reduced by 27.3%; the cost of energy was reduced by 30.3%. After the adoption of the distributed clustering algorithm, the labor cost has been reduced by 17.8%; the management cost has been reduced by 18.75%; the construction efficiency has been increased by 17.83%. When the early cost of green

building has been reduced, the achievements for the whole GBI would be unprecedented. The reduction of cost would make the GBI develop rapidly, would bring huge opportunities to the transformation of the whole BI, and promote the rapid completion of industrial upgrading of the traditional BI, so as to meet the current concept of SD of the whole society.

V. Discussion

Green building is the trend of the development of the BI in the future. The concept of SD has been fully popularized in all fields at present. The BI, as a large energy consumer, is also a serious disaster area of environmental pollution. Reform is imminent. The emergence of the concept of green building points out the direction for the reform of the traditional BI. Compared with traditional buildings, green buildings have great advantages, but at present, the development of green buildings is still relatively slow. The biggest reason for restricting the development of green buildings is that their construction costs are too high. Ant colony algorithm and distributed clustering algorithm provide new solutions to the problem of high construction cost in the GBI at this stage.

VI. Conclusion

Vigorously developing green buildings is of great significance. The development of green buildings can not only save resources, but also reduce the damage to the environment, and has advantages over traditional buildings in terms of living comfort. Green building design is more scientific. For example, in terms of site selection and ventilation, more attention should be paid to people's sense of experience. The development of green buildings is the trend of the development of the BI, and it is also the new requirement of the SD concept for the BI since the new era. In view of the biggest obstacle to the development of the GBI at the present stage, namely, the cost problem, this paper proposed a new idea to reduce the construction cost of green buildings from the overall planning, including the main use of cost and some details that need to consume cost in the subsequent use process. A new idea was put forward in an all-round way to reduce the construction cost of green buildings, thus breaking the biggest obstacle to the development of green buildings at this stage. However, it should also be noted that cost is the biggest obstacle to the development of green buildings, but not the only obstacle. In order to promote the comprehensive development of green buildings, it is also necessary to improve the level of education, and enhance people's awareness of environmental protection and the concept of SD. Only in this way can people create a hotbed for the rapid development of green buildings, fundamentally solve the problems in the development of green buildings, promote the upgrading of the industrial structure of the BI, and make contributions to the protection of the environment.

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