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Risk Identification of PPP Mode in Stadiums and Gymnasiums by Ant Colony Algorithm

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Abstract

Aiming at the problem that the PPP model of stadiums and gymnasiums cannot realize multi-dimensional risk analysis and the global risk identification ability is poor, an ant colony algorithm is proposed. Firstly, k clustering is used to cluster PPP mode data. Then, the ant colony algorithm is analyzed stochastically, and the risk set of PPP mode is obtained, which lays the foundation for later risk identification. Finally, through the random fusion function, the PPP mode risk set based on the path profile is constructed, and the optimal identification path is obtained, so as to improve the identification accuracy of PPP mode risk. MATLAB simulation shows that the ant colony algorithm proposed in this paper is superior to the risk clustering method in the overall risk identification accuracy and identification time of PPP mode. Therefore, the ant colony algorithm proposed in this paper can be used to identify the risk of PPP mode, to meet the needs of the construction of stadiums and gymnasiums.

Keywords: Risk Identification, Ant Colony Algorithm, PPP Mode, Stadiums, Gymnasiums, Simplification Rate, Index Adjustment

1. Introduction

In recent years, the state has increased the cooperation between the government and individuals in the construction of stadiums and gymnasiums[1], and made enterprises and individuals pay more attention to the risk identification of PPP mode. PPP mode is the main cooperation mode between the government and individuals in venue construction[2], which plays an important role in urban development and comprehensive fitness[3]. However, there are many risks in the implementation of PPP model, such as planning risk, outsourcing risk, capital risk and so on, and the relationship between different risks is nonlinear[4], which cannot be accurately identified by previous analysis methods. A Public–Private Partnership(PPP) is an association among the private and government investors to develop and materialize public goods, infrastructure projects, services etc. The concept of PPP was initially formed in the UK. It ensures the delivery of better results within a limited period with a minimized budget. In addition to this, this scheme attracted remarkable attention among public sectors and is widely prevalent in many countries.

However, PPP projects are characterized by large scale investments, long contract concession periods, and complex technologies, which give rise to many potential risk factors in the implementation process, which could also lead to the failure of PPP projects [8,9,10]. According to the World Bank, 279 PPP projects have been "Cancelled" since 1990 [5]. Employment of PPP mode in large scale gymnasiums and stadiums focus on three aspects: focusing on features of gymnasiums and stadiums and employing it to build large stadiums; focusing on the operation process as guidelines to leverage the resources and understand the Pareto effect and lastly comprehending the deployment of PPP mode in the operation of stadiums. The stadium and gymnasiums operation focus on three areas namely benefit sharing government supervision and risk sharing. government supervision.

(1) Risk sharing: Adhering PPP principles in stadium helps in seeking financial support and also shares the risks within the governmental and private sectors. These groups are units of investment to get capital input and on the other hand transfer risks. The performance permits investors to take part in a feasibility study, design, operation and construction to ascertain project life cycle thereby mitigating the fund diversions.

(2) Introducing Advanced Technology and Managerial: The tenders are invited from the public for the project and the companies will do the feasibility assessment to estimate the rational profit, then form capital input with risk response. The appropriate private sectors will be selected to involve. In the government sector, the competition is for lower bidding prices, more options, and forming better projects.

(3) Strengthen Public Participation: Unlike in government projects where the party leaders take decision, the PPP involves public participation. These older settings permit leaders to act foolishly thus leading to serious corruption.

Some scholars believe that intelligent function can effectively improve the risk identification rate of PPP mode and take timely risk identification measures[5]. At the same time, the intelligent function can make up for the shortcomings in manual risk analysis, verify the risks, and make the risk identification of PPP mode more accurate[6]. The combination of ant colony algorithm and artificial risk analysis can realize the optimal result calculation of PPP mode and the calculation of various risk indicators[7]. Then, the path analysis in ant colony algorithm can realize the risk probability calculation of PPP mode and simplify the PPP mode data of stadiums and gymnasiums[8]. Finally, the risk analysis of PPP mode data is carried out to calculate the optimal path[9]. Therefore, applying ant colony algorithm to the risk calculation of PPP mode in stadiums and gymnasiums can reduce the amount of initial data[10], reduce the influence of uncertain factors on the results, and identify risks from multiple angles. Some scholars have applied the ant colony algorithm to financial risk identification, and found that this method can reduce the influence of interference factors on risk calculation results and enhance the energy of risk calculation[11]. Some scholars have applied ant colony algorithm to the management scheme of stadiums and gymnasiums, and found that ant colony algorithm can identify risks from multiple angles[12]. Other scholars carried out multi-factor regression analysis for PPP model[13], and found that there is a big deviation in the calculation results, and the dispersion of the results is higher than the standard value[14], which shows that the traditional manual analysis method can not realize the comprehensive analysis of PPP model risks[15]. Based on the above background, this paper takes the PPP mode of stadiums as the research object, uses ant colony algorithm to identify the risk, and verifies the accuracy and effectiveness of the identification results.

2. Related Concepts of PPP Mode in Stadiums and Gymnasiums

2.1 Ant Colony Algorithm Description

Ant colony algorithm belongs to the probability calculation method of path optimization, which uses the random selection of ants to find an optimal probability path to solve systematic problems. At present, ant colony algorithm is widely used in machinery, management[16], engineering and other fields, and achieved good research results[17]. Ant colony algorithm has a continuous analysis function, calculating the wandering probability of different ants, and finally realizing the effective risk identification of PPP mode. Ant colony algorithm first standardizes the data of PPP mode[18], and then calculates the optimal solution of different paths. The specific assumptions are as follows.

Suppose 1: git is a multi-path risk set, where i is different ants, t is the route where different ants are located, and x is any path, then the path searched by any ant is calculated as shown in Equation (1).

$$P_j(x) = \sum_{i,t=1}^{n} \{g^j{}_{it} \cup k \mid g\} \tag{1}$$

Among them, $P_j(x)$ is the maximum risk path of risk set git.

Because the path selection of ant colony is random and normal, different paths change frequently. In order to calculate the path chosen by ant colony more accurately, it is necessary to calculate the minimum prime number in the risk set and form a prime number set is ρ.

The related theories of ant colony algorithm are as follows:

Assumption 2: The calculation function of the best path of any ant colony is $f(\cdot)$, then the calculation of the best position of the whole ant colony is shown in Equation (2):

$$\int_{x \in g_{ij}} f(x)dx - \overline{\sum_{j=1}^{n} f(P_j(x))} \cup \widehat{Q(f(x))} \tag{2}$$

Where, $Q(f(x))$ is the maximum probability function of $f(\cdot)$.

Hypothesis 3: If the following conditions of $f(x)$ can be satisfied, $f(x) < \max(x)$, $f(x)' < \max(x)'$, ..., $f(x)^j < \max(x)^j$ and the best path of any ant colony is within $f(x)'$, the error of the calculation result of the whole ant colony is less than, and the specific calculation is shown in Equation (3).

$$D(x, f(x)) = \lim_{x \to \infty} (\sqrt{x} \cup \sqrt{\log(P_j(x))}) \tag{3}$$

Where, $D(x, f(x))$ is the error ratio of any path to the whole path is between [0, 1].

The above analysis shows that the approximate integral can be used to calculate the relationship between any path and the optimal path, and the influence of interference factors on the path calculation results can be eliminated. Therefore, the constraint condition of Hypothesis 3 can reduce the influence of external factors on the optimal path of ant colony. In addition, formula (3) can effectively restrain the variation of the optimal path selection and improve the stability of the path selection process.

2.2 Risk Identification of PPP Mode in Gymnasium

Based on ant colony algorithm, this paper uses Euclidean distance to calculate the path of any ant colony, and chooses the path by random probability. At the same time, the arbitrary path is constantly adjusted to determine the relationship between the arbitrary path and the overall path. The risk identification of PPP mode can be sorted by "IF", and the specific process is as follows:

IF: $x_i \in g_{ij}$, and $S(x) = \max(x_i, y_j)$, xi, and xj are the two endpoints of the path, respectively.

then $S = \overline{\dfrac{\sum_{i=1}^{n} s(x_i) \cdot k}{q}}$

Among them, k is the weight of any path, g_{ij} is the particle set, $S(x)$ is the deviation between any path and ant colony path, and $\max(x_i, x_j)$ is the maximum Euclidean distance. Under the constraint of Euclidean distance, unreasonable paths and repeated path combinations are eliminated to reduce the amount of data in PPP mode.

Through the above analysis, if any path is x_i, the simplified risk set can be obtained by Euclidean distance sorting, as shown in Equation 4.

$$g_{ij} = \sum_{i,j=1}^{n} \bullet \exp\{\frac{(x_i - x_j)}{q}\} \tag{4}$$

Where， q is the optimal path of any ant colony; *exp* () is the expected function.

Because the path selection of ant colony is a dynamic process, it is necessary to carry out persistent analysis on the path, and the persistent calculation of risk set is shown in Equation 5.

$$g_{ij} = k \cdot \overrightarrow{\sum_{i,j,k=1}^{n} g_{ij}{}^{t} \cup (x)} \tag{5}$$

In which k is the change frequency of the optimal path, this coefficient can improve the binding force of Euclidean distance and realize the orderly selection of the optimal path. In the process of derivation, k can reduce the influence of interference factors on the optimal path, realize the dynamic and stable selection of the optimal path, and improve the accuracy of risk calculation in PPP mode.

3. Risk Identification Process of PPP Mode in Stadiums and Gymnasiums

3.1 Synergy Analysis of Different Risks

The PPP model risk identification method of stadiums and gymnasiums proposed in this paper needs to realize complex path selection and local and global eigenvalue calculation, so it is necessary to calculate the synergy of different risks, increase the convergence threshold of any path, and complete the risk synergy iterative calculation of the whole ant colony to get the optimal risk identification value.

3.1.1 Data Initialization of PPP Mode in Sports Venues

Before the ant colony algorithm analysis, we should obtain the initial value of PPP mode in stadiums and gymnasiums, ensure that the value presents normal distribution, and eliminate the data with significant correlation. At the same time, we should eliminate the local optimal solution in ant colony algorithm, reduce the influence of local optimal solution on the global solution of ant colony, and reduce the error rate of risk identification. Data initialization can improve the order of paths, expand the number of paths in risk set, and bring all possible risks into the set. The specific analysis is shown in Figure 1.

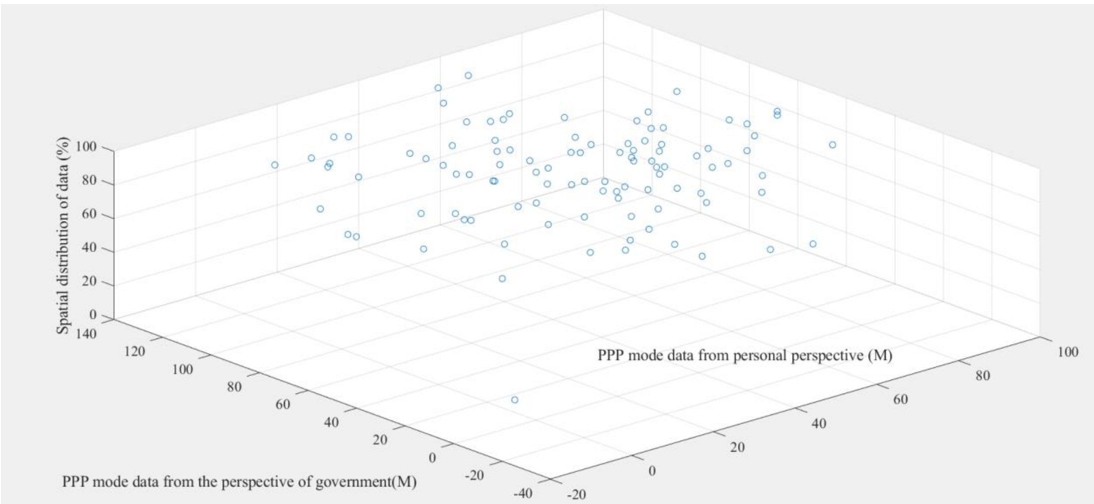

Figure 1. PPP Mode Data after Initialization

Standardize the initialized data and get the two-dimensional projection of the data. Then, the duplicate data is eliminated, so that the whole data projection is evenly distributed, which reduces the complexity of the data and simplifies the data volume of PPP mode. The specific results are shown in Figure 2.

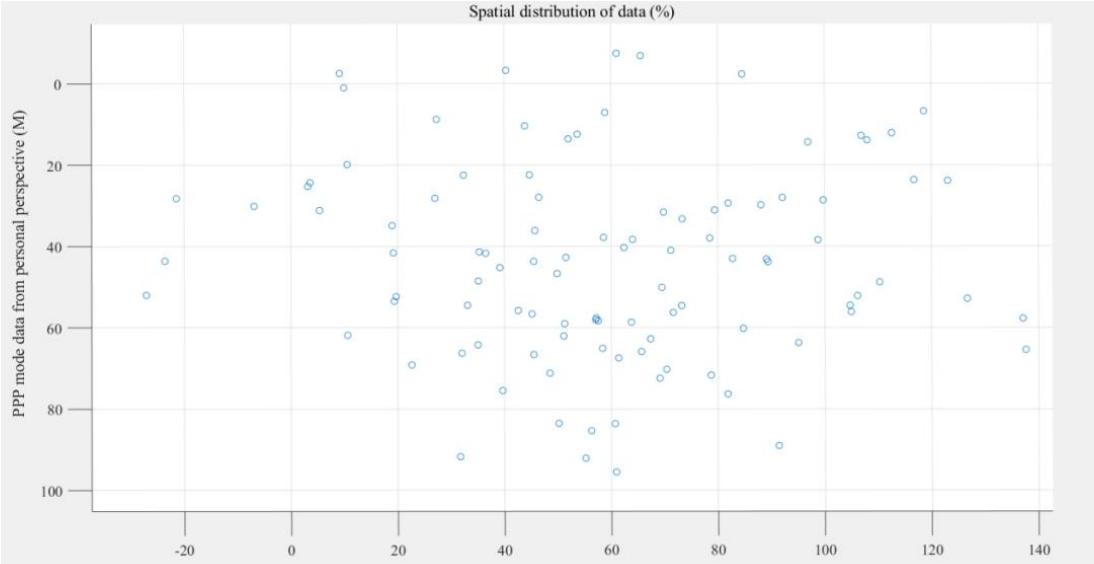

Figure 2. PPP Mode Data after Standardization Processing

Figures 1 and 2 are the standardization process of PPP mode data respectively. By comparison, it is found that the data are arranged more orderly and the processed data are more concentrated. After standardization, the data of PPP mode is not interfered with by external factors, and the independence of data is stronger, which provides a basis for risk calculation of PPP mode.

3.1.2 Different Risk Identification Strategies for PPP Mode

Different risk identification strategies carry out risk identification according to different angles, namely, personal angle, government angle and mutual benefit angle, and mathematically describe the risk identification strategies from different angles, as follows.

(1) Risk identification of PPP mode from an individual perspective, as shown in Equation 6.

$$y_{ij}(t+1)=k\bullet y_{ij}(t)+c_1\bullet\frac{[k\cdot\sum_{i,j,k=1}^{n}g_{ij}{}^{k}\{x(t)\cdot f(P_j[x(t)]\}}{mean\sum_{i,j=1}^{n}g_{ij}{}^{k}[x(t)]} \tag{6}$$

(2) Risk identification of PPP mode from the perspective of government, as shown in Equation 7.

$$y_{ij}(t+1)=k\bullet y_{ij}(t)+c_2\frac{[k\cdot\sum_{i,j=1}^{n}g_{ij}{}^{t}\{x(t)\cdot f(P_j[x(t)]\}}{all\sum_{i,j=1}^{n}g_{ij}{}^{t}[x(t)]} \tag{7}$$

(3) Risk identification of PPP mode from the perspective of mutual benefit, as shown in Equation 8.

$$y_{ij}(t+1)=k\bullet\left|\frac{[\delta\cdot\sum_{i,j=1}^{n}g_{ij}{}^{t}\{x(t)\cdot f(P_j[x(t)]\}}{B(\sum_{i,j=1}^{n}g_{ij}{}^{t}[x(t)])}\right| \tag{8}$$

(4) Risk analysis of continuous PPP mode from different angles, as shown in Equation 9.

$$y_{ij}(t+1) = A \bullet y_{ij}(t) + \sum_{i=1}^{2} c_i \bullet \frac{[k \cdot \sum_{i,j,k=1}^{n} g_{ij}^{\ k}\{x(t) \cdot f(P_j[x(t)]\}}{lin \sum_{i,j=1}^{n} g_{ij}^{\ k}[x(t)]} \tag{9}$$

Among them, c_1 and c_2 are the adjustment coefficient of risk analysis from different angles; n is different strategies, B () is a Boolean function to verify whether there is risk; Lin () is a proportional adjustment function, which reduces the evaluation difference between the government and individuals.

This paper analyzes the PPP mode data of stadiums and gymnasiums in two aspects. On the one hand, it expands the scope of risk identification as much as possible, randomly selects risk identification strategies, and verifies the results of different strategies locally and globally, thus simplifying the initial data amount of PPP mode of stadiums and gymnasiums. On the other hand, the optimal values of different paths are verified, and the globally optimal path is obtained, which is used for risk identification.

3.2 Risk Identification Steps of PPP Mode in Stadiums and Gymnasiums Based on Ant Colony Algorithm

Firstly, ant colony algorithm standardizes PPP mode data, then selects different paths, and calculates the local optimal value and global optimal value of paths. Finally, compare the optimal values of different paths and output the maximum risk of PPP mode. The specific steps are as follows.

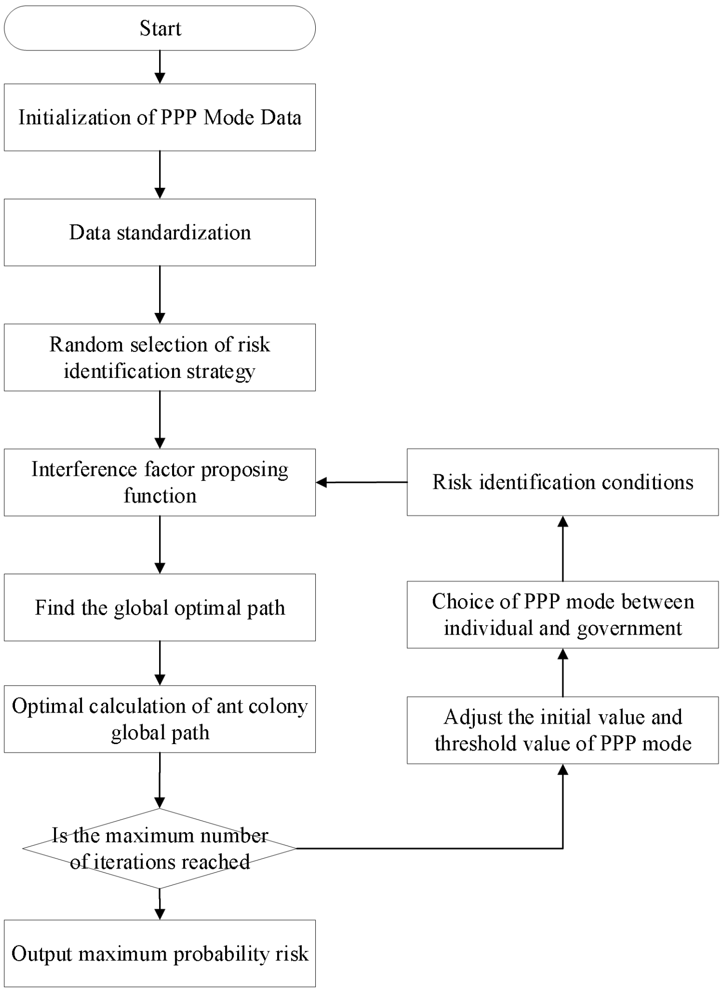

Figure 3. Risk Identification Process of PPP Mode in Stadiums and Gymnasiums Based on Ant Colony Algorithm

Step 1: Determine the interference factors and data structure of PPP mode data, and determine the sequence of different risks according to the data characteristics of PPP mode of stadiums and gymnasiums. The initial weights of PPP model data of stadiums and gymnasiums are carried out to form different risk analysis sets, and each set is analyzed by ant colony randomness and path selection probability.

Step 2: Data initialization in PPP mode. Randomly initialize the related parameters of PPP mode data. Set the maximum value of PPP mode data, weights of different paths, and calculate the eigenvalues of each path.

Step 3: Build the tuning function. Using ant colony algorithm to compare the PPP model data, through formula (1) ~ (7) to select the corresponding risk identification strategy, calculate the global eigenvalue, and calculate the maximum probability of risk.

Step 4: If all the data of PPP mode are calculated, stop the calculation and return the maximum probability of PPP mode risk, otherwise repeat steps 2 ~ 3.

4. Case Analysis of PPP Mode Risk Identification in Stadiums and Gymnasiums

4.1 Introduction of PPP Mode in Stadiums and Gymnasiums

This paper takes PPP mode data of municipal stadiums and gymnasiums as samples and analyzes project cost, construction period, project cost, financing situation, functions and so on. The PPP mode risk identification standard of the sample refers to the Measures for the Administration of PPP Mode in Stadiums and Gymnasiums, the Regulations on the Administration of Personal Financing and the Measures for the Administration of Engineering Construction Projects, and judges the risk levels of each content, which are divided into five levels: high risk, medium risk, low risk, low risk and normal risk. The deadline for collecting PPP mode data is December 30th, 2022, and the data results are shown in Table 1 [19]. The criterion for data collection is based on the funding, engineering, cost, operation or function and the construction duration of the stadiums and gymnasiums. The data volume and the percentage of involvement are also procured for better understanding. The percentage of government and private shares is also included in the study. The engineering costs includes the costs for auditing, accounting and other management operations. Also, the construction expenses comprise of providing facilities for construction and maintenance costs.

Table 1. PPP Mode of Stadiums and Gymnasiums

content	Data volume (pcs)	Percentage (%)
Funding: Government and individual cooperation, individual financing 4.5 percent, government contribution 5.5 percent	1202	20.82
Engineering expense management, including auditing, accounting, accounting, operation	432	7.48
Construction period: main project construction period, auxiliary facilities construction period, later maintenance project construction period	2032	35.19
Function: government functions, personal functions	1041	18.03
Project cost: third-party cost, government cost	1067	18.48

4.2 Risk Identification Criteria for PPP Models in Stadiums

The PPP mode data is analyzed in three aspects: standard identification, standardized processing, data complexity and local eigenvalue elimination, so as to ensure the accuracy of risk calculation of PPP mode in the later period.

The data standardization processing of PPP mode is calculated as Equation 10.

$$f(x) = k \bullet \sum_{i=1}^{n} \widehat{[x_i^2]} \tag{10}$$

The data complexity of PPP mode is calculated as Equation 11.

$$f(x) = \sum_{i=1}^{n} [x_i^2 - \max[10\pi(2\pi x_i)] + \pi] \tag{11}$$

The local risk eigenvalue of PPP mode data is eliminated and calculated as Equation 12.

$$f(x) = -20\exp\{-0.2\sum_{i=1}^{n} \sqrt{\widehat{\sum_{i=1}^{n} x_i^2}\}} - \exp\{\widehat{\sum_{i=1}^{n}\cos(2\pi x_i)}\} \tag{12}$$

Where, n is the amount of PPP mode data, x_i is any PPP mode data, and the value range is [-1, 1]. In order to ensure the rationality of data processing results, take multiple averages as the final result, and the specific calculation results are shown in Table 2.

Table 2. Results of the Calculation

Process content	Algorithm	The value changes		Average difference	Standard deviation
Standardized processing	Ant colony algorithm	0.79		0.16	3.05
	Risk clustering methods	2.32		1.42	4.25
Data complexity	Ant colony algorithm	0.73		0.48	2.81
	Risk clustering methods	2.26		1.54	4.44
Local eigenvalue culling	Ant colony algorithm	0.56		0.10	2.40
	Risk clustering methods	1.86		1.10	5.30

As can be seen from Table 1, the data of different contents meet the test requirements in standard deviation, mean value and standard deviation. Among them, PPP mode data processing results are better than ant colony algorithm, which shows that the former is better for data processing. The efficacy of the model is validated on the grounds of risk stability, error rate, simplification rate and preserving integrity in the risk calculation mode.

4.3 Risk Identification Results

4.3.1 Stability of Risk Identification Results

In order to further prove the research results of ant colony algorithm, the stability analysis of the data in Table 1 is carried out, and the results are shown in Figure 4.

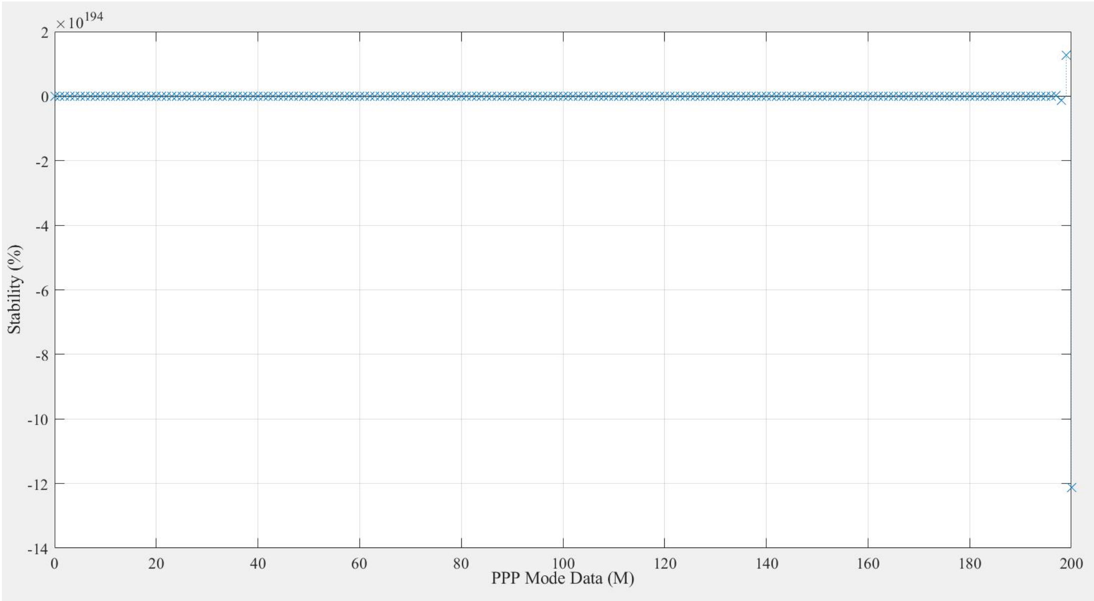

Figure 4. Risk Identification Stability of PPP Mode in Stadiums and Gymnasiums

It can be seen from Figure 4 that the ant colony algorithm has a small change range and high stability in identifying the risks of PPP mode data, which shows that the ant colony algorithm can continuously identify the risks of PPP mode data. Relatively speaking, the risk clustering method of the identification range of fluctuations, mainly by the ant colony algorithm for PPP model data standardization processing, resulted in better changes in the research results.

4.3.2 Error Rate of Risk Identification Results

Error rate is an important index of risk identification results, and it is also the guarantee of accuracy. With the increase of PPP mode data, the error rate of risk identification by different methods should be stable, otherwise, the calculation accuracy will be affected. The specific results are shown in Figure 5.

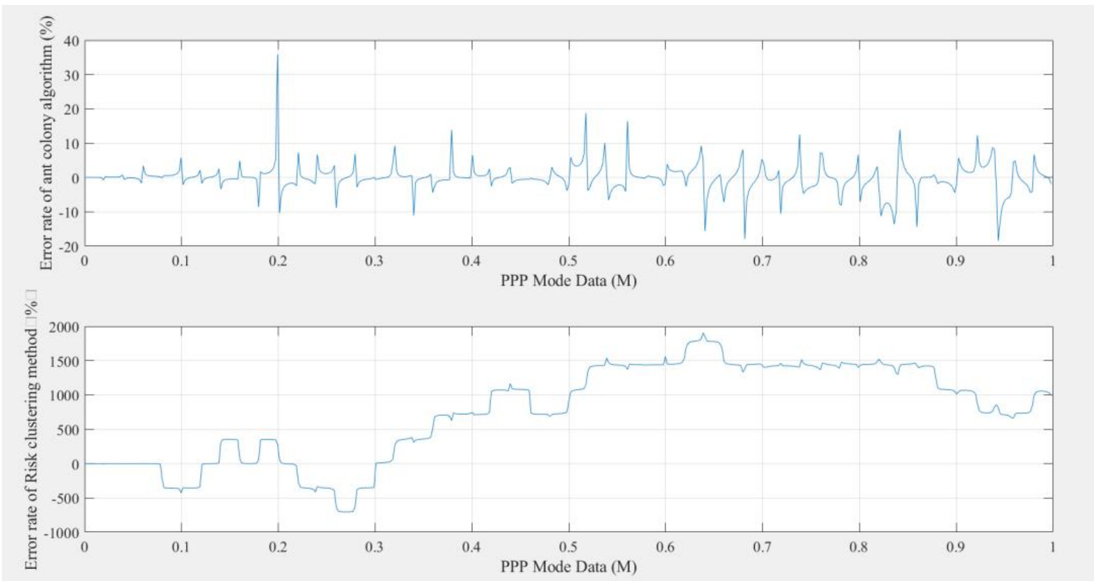

Figure 5. Error Rate of PPP Mode Risk Identification of Different Algorithms

As can be seen from Figure 5, the error rate of ant colony algorithm to PPP mode risk fluctuates, which shows that the accuracy rate of ant colony algorithm is high and changes within the allowable range. Relatively speaking, the error rate of risk clustering method rises linearly, which shows that the calculation error of PPP mode risk increases continuously, and the accuracy rate decreases due to avoidance.

4.3.3 Simplification Rate of PPP Mode Risk

The large amount of data in PPP mode involves not only project cost, construction period, project cost, financing situation, function exertion, etc., but also continuous analysis of data, so the corresponding data should be simplified, and the specific simplified results are shown in Figure 6.

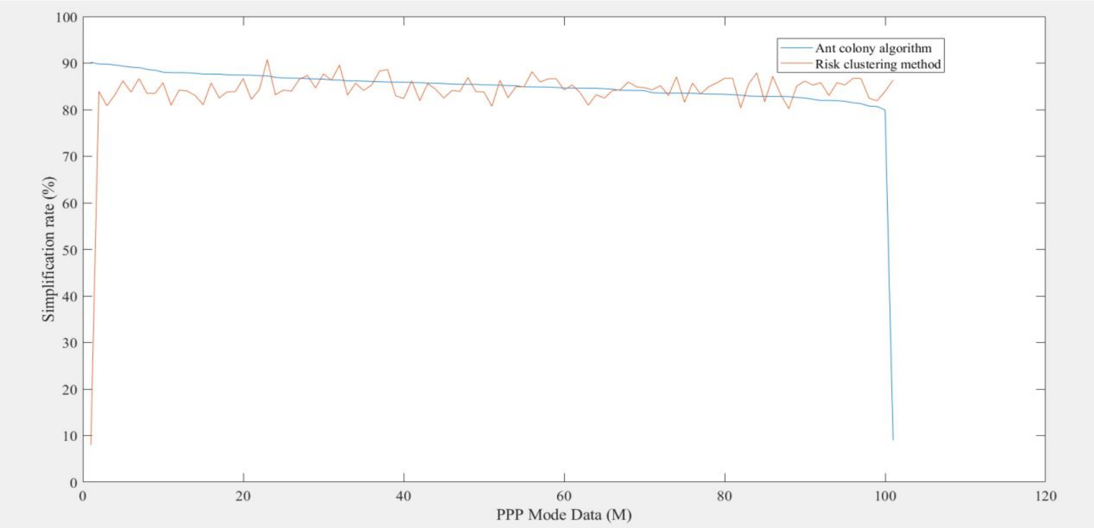

Figure 6. Simplification Rate of PPP Mode Risk

As can be seen from Figure 6, the simplification rate of PPP mode risk data by ant colony algorithm shows a straight decline, which shows that ant colony algorithm has a high simplification rate of data and can realize internal iterative analysis. Relatively speaking, the simplification rate of the risk clustering method presents a fluctuation analysis, which shows that this method is unstable in calculating the risk of PPP mode. The main reason is that ant colony algorithm process risk processing analysis and realizes the preprocessing of initial data.

4.3.4 Integrity of Risk Identification

In order to verify the effectiveness of the ant colony algorithm proposed in this paper, a comprehensive analysis of PPP mode risk identification results is required, and the results are shown in Figure 7.

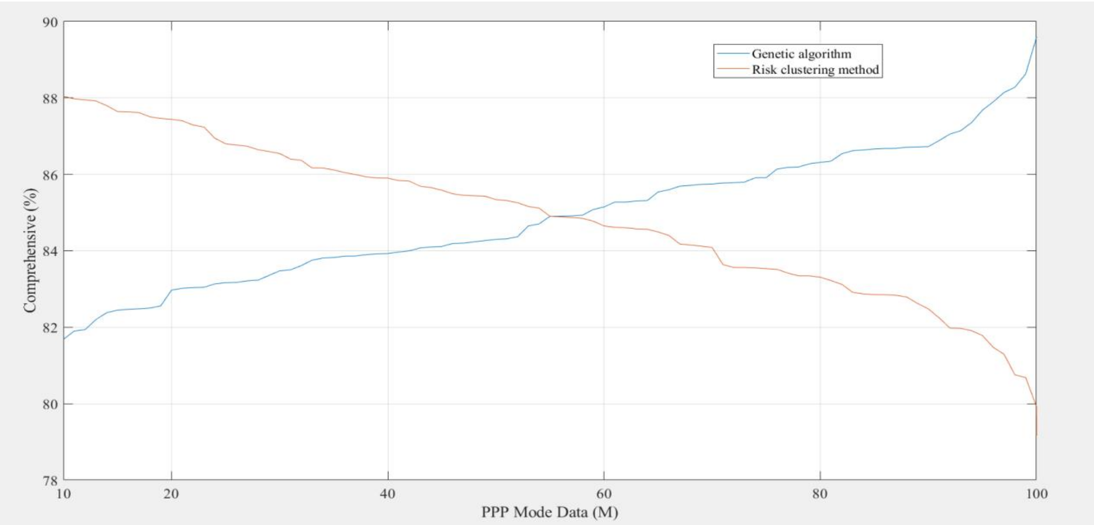

Figure 7. Comprehensive Analysis of PPP Mode of Stadiums and Gymnasiums by Different Algorithms

As can be seen from Figure 7, the ant colony algorithm has higher comprehensiveness and a smaller change range, which is superior to the risk clustering method. The calculation accuracy and time of both are shown in Table 3.

Table 3. Recognition Accuracy of Different Levels

algorithm	Identification accuracy (%) for different risk levels					Calculation time (seconds)
	High risk	Medium risk	General risks	Lower risk	normal	
Ant colony algorithm	96.23	92.22	96.28	98.34	95.94	12.23
Risk clustering methods	52.32	69.13	77.33	43.47	86.91	32.32

It can be seen from Table 3 that the calculation accuracy of ant colony algorithm is more than 90%, while the calculation accuracy of the risk clustering method is about 50 ~ 90%. Therefore, ant colony algorithm has better accuracy and calculation time. The reason is that ant colony algorithm adjusts the project cost, construction period, project cost, financing situation, functions and other aspects by setting the risk synergy factor of PPP mode.

5. Conclusion

In this paper, an ant colony algorithm is proposed to identify the risk of PPP mode in stadiums and gymnasiums. This method can improve the accuracy of PPP mode risk identification by setting constraints, standardizing risk data and selecting risk identification strategies. The results show that, compared with risk clustering method, ant colony algorithm has better recognition accuracy, stability and error rate, and can identify the risk of PPP mode in stadiums and gymnasiums, and the calculation time is shorter. The comparison between the ant colony and risk clustering methods shows that the former shows better performance. However, ant colony algorithm pays too much attention to the ability of global risk identification, which leads to a large amount of PPP mode data rejection and indirectly affects the calculation results. This can lead to over-fitting of results, which is not good for any model. Therefore, in future research, the index adjustment coefficient will be increased for improvement.

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