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Water resources supply chain of South-to-North Water Transfer Project

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ABSTRACT

In this paper, the principal component analysis was used to extract the water supply information characteristics of the water supply chain of the South-to-North Water Diversion Project. The supply risk assessment model of the water resources supply chain of the South-to-North Water Diversion Project was designed. Experimental results show that compared with traditional methods, the method of 120 times of experiments, the proposed method is of the highest recognition rate is about 98%, water supply risk probability prediction results and the fit of the actual results of changes within the range 85%–100%, and the method for water supply feature extraction of the accuracy of about 95% on average, miss rate of about 20% on average. Experimental data verify the effectiveness of the proposed method.

Keywords: South-to-North water diversion; Water supply chain; Node correlation; Water supply; Risk assessment; Principal component analysis

1. Introduction

The middle route of the South-to-North Water Diversion Project is a strategic project to alleviate the shortage of water resources in the northern region and optimize the allocation of water resources in China. The 1,432 km project, which starts from The Danjiangkou Reservoir in Hubei Province in the south and reaches the Tuancheng Lake in Beijing and the Outer Ring River in Tianjin in the north, is the world's largest inter-basin Water Diversion Project. The complicated geological conditions and meteorological conditions along the middle route of the South-to-North Water Transfer Project make the safety of the South-to-North Water Transfer Project seriously challenged [1]. The eastern route of the South-to-North Water Diversion Project is planned to be implemented in three phases. At present, the construction of the first phase of the eastern route has been started. When completed, the project will form a large water supply system connecting the Yangtze River, Huaihe River, Yellow River and Haihe River, which will involve the interests of five provinces and cities and numerous water departments. Under the condition of a socialist market economy, how to guarantee the normal operation of such a complex giant water supply system is a new subject that has never been encountered in the allocation and operation management of water resources in China so far, and there is no ready experience for reference abroad. As the construction of the first phase of the eastern route of the South-to-North Water Transfer Project has been started, how to optimize the allocation of water resources and ensure the normal operation of the water supply system of the first phase of the eastern route of the South-to-North Water Transfer Project has become an urgent task for the eastern route project. In order to assess the supply risks of the water resources supply chain of the South-to-North Water Diversion Project, more than 60,000 sensors have been installed along the South-to-North Water Diversion Project to collect engineering safety data in real-time, so as to realize the purpose of full time and all-round understanding of engineering safety [2]. However, the massive data collected by the sensor also has the problem of a large amount of data but a small amount of information. Therefore, the supply risk assessment of the water resources supply chain of the South-to-North Water Diversion Project needs to be further studied.

At present, some good research results have appeared in this field. Gim et al. [3] proposed the supply risk assessment method of the water resources supply chain of the South-to-North Water Diversion Project based on the improved VAR method. After comparing several VAR methods, the Monte Carlo simulation method is selected as the main tool to evaluate supply chain risk, and the two deficiencies of the Monte Carlo simulation method are improved. A three-level multi-supply chain network and a three-level multi-supply chain risk assessment model are constructed to achieve the assessment of the supply risk of the water resources supply chain from the South-to-North Water Diversion Project. However, the risk assessment rate of this method is low in the application process, so it cannot fully assess the supply risk of water resources. Zhao et al. [4] propose a supply risk assessment method for the water resources supply chain of the South-to-North Water Diversion Project based on the hierarchical model of the Internet of Things. Taking the risk factors of the supply chain as the research object and taking the accident tree model as the foundation, the risk factor tree diagram based on the accident tree model is constructed. It was mapped to Bayesian Network, and the influence of human factors was reduced by triangular fuzzy number processing in combination with the risk factor values given by experts. Finally, the importance of each basic event was analyzed and ranked through forward and reverse reasoning, so as to effectively evaluate the risk of each event quantitatively. The risk assessment rate of this method is high, but the assessment results are quite different from the actual results, which does not meet the current accuracy requirements in this field.

In order to solve the problems existing in the above traditional methods, this paper designs the water supply chain structure of the South-to-North Water Diversion Project, which includes the analysis of the overall characteristics of the water supply system, the structural design of the water supply system, the control of "three flows", the operation performance evaluation, the research on the water supply contract relationship and the risk control research. Principal component analysis (PCA) technology was used to extract the water supply information characteristics of the South-to-North Water Transfer water supply chain. Based on this, the correlation of water supply chain nodes was obtained and a water supply risk assessment model was constructed. The experimental results show that the proposed method has a high-risk identification rate and accuracy, and the average missed detection rate of risk assessment is lower, which provides a reliable basis for research in related fields.

2. Water resource supply chain structure and supply information feature extraction

The water resources supply chain of the South-to-North Water Diversion Project is a multi-level structure composed of a series of organizational structures, such as the water resource provider – the Yangtze River pumping port, the water resource distributor – large node lake reservoirs, and the water resource demander – the water area around the lake. In the water supply chain, the only products available for sale is the engineering of water resources, and through the goods prior to build up water supply channels of distribution and storage, and finally to those hands into the water, this a series of activities constitutes the whole process of water resources of the south-north water diversion water supply chain, this article is mainly from the perspective of water control and allocation of water resources in the supply chain project of South-to-North Water Transfer Project water were studied. In the south-north water diversion water supply chain, the core management idea is through water supply chain each node on the lake or regional cooperation and division of labor between, optimizing and integrating water flow, information flow and cash flow in the supply chain, improve the efficiency of the water resources allocation of the South-to-North water transfer routes, achieve project goals.

2.1. Structural design of water supply chain of South-to-North Water Diversion Project

The water resources water supply system of the South-to-North Water Diversion Project is an open and complex large water supply system with multi-basin, multi-source and multi-objective, which involves the interests of many provinces and cities in the north and many water departments. In such a complex water resources allocation of the water supply system, in order to realize scientific, reasonable, efficient and convenient construction of water control and allocation of water resources, reasonable coordination between regions, between departments of water resources demand, to achieve the optimal allocation of the water area of water resources, ensure to achieve the goals of the south-north Water Diversion Project planning, maximize benefits, this is a difficult thing.

In supply chain management of water resources research, should first clear the object of study of the specific structure and the composition of the members of all nodes, for the research of the south-north water diversion water supply chain is not exceptional also, should be the first to analyze the composition of the water resources supply chain structure, and the structure design and other content in the research of the south-north water diversion water supply chain to carry out the important basis. Considering the current administrative system of our country, we can divide the whole water supply system of the South-to-North Water Transfer Project into different water supply sub-systems according to the several major lakes and reservoirs of the project route [5]. From the perspective of water resources supply chain management, these large-scale water supply systems are equivalent to sub water supply systems of the water resources supply chain, and they can be considered as a parallel connection. For details, please refer to the relevant research contents in this chapter. On the basis of communication and coordination, the whole water transfer and water supply system is in a balanced state by signing a water supply agreement. In each large water supply system, it can be subdivided into several sub-links, and constitute a serial chain of water resources sub-water supply system. At the same time, due to the project runs through the city quite a few, the supply of water users are numerous, and it is very difficult in the process of study, considering all areas and user one by one, therefore, how to choose appropriate diversion of water resources of the supply chain members of each node and the composition of each node and important content of the water resources supply chain structure design.

This paper introduces the theory of water supply chain management to study the operation and management of the South-to-North Water Diversion Project and puts forward the concept of the water supply chain of the South-to-North Water Diversion Project [6]. Diversion of water resources of the supply chain theory research content is more, which mainly includes the analysis of characteristics of water supply system's overall structure, water supply system design, the "three flow" operation control, performance evaluation, the relationship between the water supply contract research as well as risk control research, the research content basic constitutes the theoretical research of the south-north water diversion water supply chain framework, its specific structure as shown in Fig. 1.

From in this paper, we give the south-north water diversion water supply system of supply chain research framework chart we can see that in the south-north water diversion water supply chain in the study of water supply system mainly includes the following aspects, namely the design of the diversion of water resources supply chain structure, water supply chain, information flow and cash flow of the water resources control, water supply, water supply contract relationship between system operating performance in evaluation and water of the lake project control and

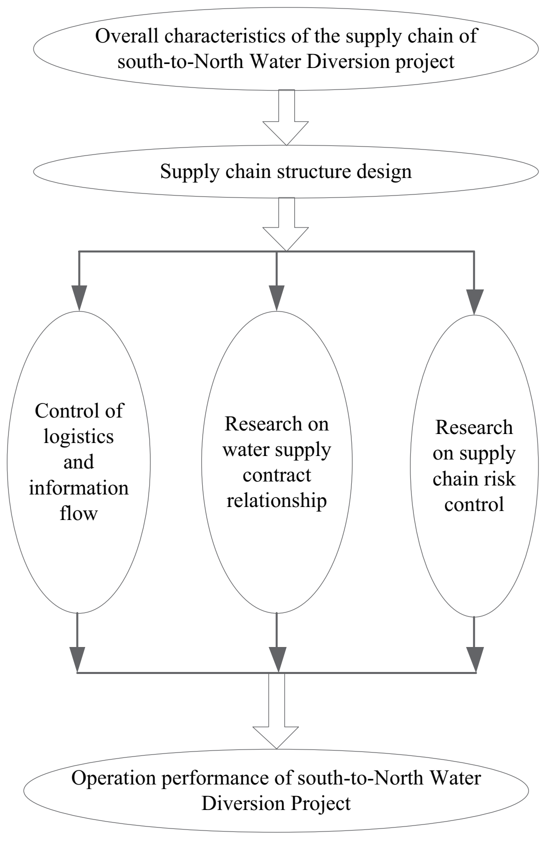

Fig. 1. Basic research framework of water supply chain of South-to-North Water Diversion Project.

allocation of water resources, etc., in this paper will be the brief analysis of research on these aspects.

First of all, the structure of the water supply chain is hierarchical and multilevel. In the structure of the water resources supply chain, although each node enterprise is one of the important members of the supply chain of water resources, if from the point of view of organizational boundaries, the nodes enterprises due to the water resources in the supply chain's position are different, so their role in the water supply chain is also different, so from that point of view, the structure of the water resources supply chain is administrative. Moreover, with the continuous complexity of supply, production and sales relations, there are more and more members of the water supply chain, and the relationship among each member is also multilevel, which increases the difficulty of water supply chain management, but is conducive to the optimization and combination of the water supply chain. Secondly, the structure of the water supply chain is bidirectional. From a horizontal perspective, entities using a common resource such as raw materials, semi-finished products or products both compete and cooperate with each other. From a vertical perspective, the structure of the water supply chain reflects the water, information flow, capital flow and knowledge flow from raw material suppliers to manufacturers, distributors, retailers and customers [7].

Secondly, the structure of the water supply chain is dynamic. Due to the water supply chain is the product of the market economy, and water resources supply chain members to join, often also is voluntary, so in the fierce market economy environment, the water resources of the supply chain members have every right to choose the most conducive to the development of their enterprise's water supply chain network, at the same time, the water resources supply chain from the perspective of global optimal choosing the right partners, therefore, the water resources of the supply chain member relationship due to the customer demand and the market environment change and often adaptive adjustment.

Finally, the structure of the water supply chain has the characteristics of transcending the geographical limits. In the structure of the water resource supply chain, each nodal enterprise entity has gone beyond the limitation of space scope and cooperated closely in business to jointly accelerate water resource and information flow, thus creating more benefits of the water resource supply chain. As a result, suppliers, manufacturers and distributors around the world can be linked together to form a global water supply chain structure.

2.2. Supply information extraction of South-to-North water diversion supply chain based on PCA

Compared with the general enterprise water supply chain, the south-north water diversion water supply chain has many characteristics, therefore, in the south-north water diversion water supply chain of defining the connotation of water resources will need to be, this study argues that the supply chain security and timely delivery of water, the water quality of water resources protection information flow involves the water demand forecasting, supply and demand of information transmission, monitoring and early warning of the water quality of water, and how to control node lake project with the quantity of water resources and water resources allocation problem, and so on. The water resources and water supply system of the South-to-North Water Diversion Project is affected by many factors, such as meteorology, hydrology, operation management and facility operation condition, and incomplete information is often one of the important factors that trouble the operation of the complex water supply system. Under the condition of incomplete information, the idea of water supply chain management is applied to design, plan and control the water resources and information flow in the water supply chain of water resources supply system, and the supply of water resources is decomposed and controlled, so as to make the supply of water resources in the South-to-North water diversion water supply system reasonable and orderly [8].

Principal component analysis (PCA) was used to extract the information characteristics of water resource dynamic supply variables that were input into the water supply chain of the South-to-North Water Diversion Project. The detailed implementation process is as follows:

Assuming that $X_K^0 \in R^{k\times p}$ represents the original data of water resource supply chain, K represents the number of samples of the data, and p represents the number of original variables, $X_K^0 \in R^{k\times p}$ is standardized by using the following formula [9]:

$$X_K = \frac{t_1p_1^T + t_2p_2^T + t_hp_h^T + \cdots t_pp_p^T}{X_K^0 \in R^{k\times p} \cdot (K \times p)} \quad (1)$$

where $t_1p_1^T$, $t_2p_2^T$, $t_hp_h^T$, $t_pp_p^T$ respectively represent the score vectors of the original feature data.

The principal component of the water resource supply characteristics of each water resource supply chain is the ratio of the variance between the original water resource supply characteristics and the total variance of the water resource supply characteristics data, that is, the contribution rate of the principal component of the water resource supply characteristics to the total variance of the characteristic samples. Assumptions, by $h(h \leq p)$ representative each water supply features contain the number of principal component use $h(h \leq p)$ instead of the original p characteristic variables, the original water supply and require $h(h \leq p)$ to p. A raw water supply features of introduction to all variables can provide information, using PCA to enter the water resources supply chain supply information extraction of dynamic variables [10]:

$$\mathrm{CPV}_h = \frac{\sum_{\mathrm{ih}}^{h} \lambda_{\mathrm{ih}} / \sum_{\mathrm{ih}}^{h} \lambda_{\mathrm{ih}}}{h(h \leq p) \times p} \quad (2)$$

where λ_{ih} represents the eigenvalue of the water supply covariance matrix.

The correlation distribution between the types of potential water supply characteristics extracted by using high-order statistical moments and the types of water supply in the water supply chain:

$$\mathrm{Muin}(y^0, z_h^0) = \frac{p(y^0, Z_h^0)}{\mathrm{CPV}_h} \cdot \frac{p(y^0, Z_h^0)}{p(Z_h^0)p(y^0)} d(z_h^0) dy^0 \quad (3)$$

where $p(Z_h^0)$ and $p(y^0)$ are the marginal probability densities of features Z_h^0 and y^0, $p(Z_h^0, y^0)$ represents the joint probability densities of water resource recharge features, $d(z_h^0)$ represents conditional entropy, and dy^0 represents information entropy [11].

The following formula is used to calculate the interval between the maximum and minimum entropy of potential water resource recharge feature information:

$$\theta_{\mathrm{step}} = \frac{\left(\theta_{\mathrm{Muin}}^{\mathrm{Max}} - \theta_{\mathrm{Muin}}^{\mathrm{Min}}\right) / N_{\mathrm{MI}}}{\mathrm{Muin}(y^0, z_h^0)} \quad (4)$$

where $\theta^{\mathrm{Max}}{}_{\mathrm{Muin}}$ and $\theta^{\mathrm{Min}}{}_{\mathrm{Muin}}$ represent the minimum and maximum of all information, and N_{MI} represents the weight norm of water resource replenishment characteristics.

The following formula is used to calculate the threshold value of potential water supply characteristics selection of the water resource supply chain represented by θ_{Muin} [12]:

$$\theta_{\mathrm{Muin}} = \frac{n_{\mathrm{MI}}}{N_{\mathrm{MI}}} \frac{\left(\theta_{\mathrm{Muin}}^{\mathrm{Max}} - \theta_{\mathrm{Muin}}^{\mathrm{Min}}\right)}{\theta_{\mathrm{step}}} \quad (5)$$

where n_{MI} represents the weight of water resource replenishment characteristics.

The following formula is used to select potential water supply characteristics of water resource supply chain:

$$\xi_{z_h^0} = \begin{cases} 1, \mathrm{Muin}(y^0, z_h^0) \\ 0, \theta_{\mathrm{Muin}}, h' \end{cases} \quad (6)$$

where h' represents the selected quantity of water supply characteristics of water resource supply chain.

Above all that, in the process of the water resources for water supply chain supply detection, based on PCA first supply information of input water supply chain dynamic variables are extracted, water supply characteristics variables in eliminating the collinearity between, on the basis of the potential feature variables selection, to achieve the risk assessment of the water supply chain to provide the basis.

3. Establishment of supply risk assessment model for water resources supply chain

In the water supply chain of the South-to-North Water Diversion Project, there is only one product, namely engineering water resources. And factors influencing the demand for water resources engineering in the node area, such as climate change, economic development, the uncertainty of these factors are often brought to the water supply system of water diversion water supply chain bigger risk, so for the south-north water diversion water supply chain, risk control research of water supply system is more important [13,14]. The research on risk control in the water supply chain of the South-to-North Water Diversion Project mainly includes risk prediction, risk control strategy and risk compensation system.

3.1. Water supply chain node correlation

There is a special relationship between the nodes of the resource supply chain and the water resource supply. The water resource supply chain is interrelated and influenced by each other. In other words, not all the nodes of the water resource supply chain can achieve the ideal water resource supply effect. Therefore, it is necessary to analyze and deal with the node correlation of the supply chain which will affect the water supply.

In order to facilitate the study of the correlation of water supply chain nodes, the relevant concepts were first set. The equipment in the water supply system is regarded as a water supply chain node, and the water supply system operator or application service on the equipment is regarded as the main body on the water supply chain node. Take node n of this water resources supply chain and the main body u of this water resources supply chain as n number pair (n,u), and regard this number pair as A part of this water resources supply chain node n, denoted as D_{nu}. In a water supply system, various computers are connected together by a network cable. The various information and data transmitted by the network cable can gener`ate many kinds of logical relations between the components of multiple computers. This relationship is the node correlation of the water supply chain.

The node correlation of the water resource supply chain is set as follows: When an abnormal influence factor successfully affects node A of the water resources supply chain, the relation between component D_{Ai} on node A of the water resources supply chain and component D_{Bj} on node B of the water resources supply chain is used to conduct visits, which will jointly affect node B of the water resources supply chain. Therefore, this relationship between nodes of the water supply chain makes it easy for abnormal influencing factors to affect all nodes of the water supply chain that are related to node A of the water supply chain [15]. This relationship is the node correlation of the water resource supply chain from component D_{Ai} to component D_{Bj}. In order to avoid confusion, the relationship between water supply chain nodes A and B can be denoted as $\mathrm{NNC}_{\mathrm{Ai:Bj}}$.

In order to express more concisely, the security risk information of $\mathrm{NNC}_{\mathrm{Ai:Bj}}$ can be represented by the ordered six-tuple $\langle A,i,B,j,P,W\rangle$, where i, j are the subjects on the nodes A and B of the water resource supply chain respectively. P represents the probability of influencing the success by using the node relation of the water supply chain, $P\in[0,1]$; W represents the impact of one water supply chain on another, $W\in[0,+\infty]$.

3.2. Risk assessment based on node correlation of water resource supply chain

A cloud model can use language values to implement an uncertain transformation between a concept and a value. The uncertainty is mainly divided into two points: fuzziness and randomness, and the correlation between them. In the cloud model, the cloud is composed of many cloud droplets, and the important features of the qualitative concept can be expressed through the shape of the cloud [16]. The cloud is expressed by the three values of expected value Ex, entropy En and superentropy He, denoted as C(Ex,En,He), which is the vector feature of the cloud.

In the network, when the device host is affected, the CPU occupancy rate and memory occupancy rate of the host will change abnormally, and the change degree is the magnitude of the risk associated with the nodes of the water resource supply chain. Therefore, the degree of risk can be evaluated according to the abnormal changes in water supply system equipment. The attack of abnormal influencing factors has strong randomness. Risk assessment for the relationship among water resources supply chain nodes most uses language to describe, make results ambiguity exists; of or relating to changes in parameters that occur when a network device is attacked. Therefore, quantitative and qualitative conversion must be carried out to determine the correlation between fuzziness and randomness. This allows for a more accurate assessment of the risks associated with node linkages in the water supply chain [17,18]. The cloud model combines the fuzziness and randomness of qualitative concepts, as well as the correlation between these two characteristics, to form the transformation between qualitative and quantitative. The cloud model is used to express and describe the correlation between water supply system parameters and corresponding changes, so as to realize the accurate assessment of the risk of the correlation between water supply chain nodes.

The risk assessment model of node correlation of water resource supply chain is set as follows:

$$W=\left(F,V,E\right) \tag{7}$$

where F,V,E represent the factor set and the weight set respectively.

Expression of factor set:

$$F=\left(F_1,F_2,\cdots,F_n\right) \tag{8}$$

Type: $F_1,F_2,\ldots,F_n$ represents n factors that affect the risk assessment results of node correlation of water resource supply chain, such as CPU utilization rate, equipment response time, etc.;

Expression of weight set:

$$V=\left(V_1,V_2,\cdots,V_n\right) \tag{9}$$

Type: $V_1,V_2,\ldots,V_n$ represents the weight of each factor in the factor set, and satisfies $V_1+V_2+\ldots+V_n=1$, $V_i>0(0\le i\le n)$;

The risk assessment value set of node correlation in the water resource supply chain is set as follows:

$$E=\left(\text{high},\text{higher},\text{lower},\text{low}\right) \tag{10}$$

Set the water supply system variable cloud as follows:

$$\text{Cloud}=\left(S,T,\text{Ex},\text{En},\text{He}\right) \tag{11}$$

where S is the collection of network resources to collect samples, and T is the interval of collecting samples.

The objective of the risk assessment method studied in this paper is: according to the current variable value of water supply system, it can directly receive the prompt from the security risk of the water supply system, so as to accurately assess the risk of node correlation of water resources supply chain [19]. According to the actual number of samples collected, calculate C(Ex,En,He) and cloud model, and then use cloud similarity algorithm to calculate the similarity between cloud and concept cloud, and finally regard the highest similarity degree as the output value [20]. Cloud similarity algorithm is to generate a certain number of cloud drops and measure the similarity degree of clouds according to the distance between cloud drops [9–11]. The specific process of cloud similarity degree algorithm is as follows:

- The forward cloud generation algorithm is used to form n cloud drops of C_0 and C_1, while the abscissa of cloud drops is retained, which are expressed as follows:

$$\text{drop}_0(n)=\left(x_0(1),x_0(2),\cdots,x_0(k),\cdots,x_0(n)\right)$$
$$\text{drop}_1(n)=\left(x_1(1),x_1(2),\cdots,x_1(k),\cdots,x_1(n)\right)$$
$$\left(1\le k\le n\right) \tag{12}$$

- sort(drop$_0$(n)), sort(drop$_1$(n)), according to the value of abscissa, cloud drops are sorted from small to large.
- The cloud droplets in (Ex – 3En, Ex + 3En) were screened.
- The cloud droplets located in (Ex – 3En, Ex + 3En) were screened and n_0, n_1 cloud drops were obtained.
- Suppose l = min(n_0,n_1), $n_0 < n_1$, then cloud droplet drop′$_1$ has $C_{n_1}^{n_0}$ combinations $\text{drop}'_{1k}\left(k\in\left(1,2,\cdots,C_{n_1}^{n_0}\right)\right)$, if $n_0 > n_1$, calculate in a similar way.
- The distance between cloud drops drop′$_0$ and drop′$_1$ is calculated:

$$\text{dis}(k)=\left(x_{(0)k}-x_{(1)k}\right)^2\left(k\in\left(1,2,\cdots,C_{n_1}^{n_0}\right)\right) \tag{13}$$

where dis(k) is the distance between drop'_0 and drop'_1, and $C_{n_1}^{n_0}$ is the number of cloud drops.

- Set the distance between each cloud drop as follows:

$$d=\text{Sqrt}\left(\sum\text{dis}(k)/C_{n_1}^{n_0}\right)/l \tag{14}$$

- Set the similarity degree of each cloud drop as: $s_1 = 1/d$, the smaller the distance between them, the higher the similarity degree and.

The cloud similarity algorithm can also be used to calculate the similarity degree s_2,s_3,s_4 of cloud C_2,C_3,C_4 corresponding to other standards, compare all similarity degree s_2,s_3,s_4, and select the cloud $C_i(1 \le i \le 4)$ corresponding to the largest similarity degree $s_i(1 \le i \le 4)$, which is the closest cloud to C_0, that is, the risk assessment value of the node correlation of water resources supply chain.

Combined with the maximum similarity value, the security risk of the node of the water resource supply chain is quantified, denoted as $R_k(t)$. Combined with the weight of water resource supply chain nodes in the network and the risk value of water resource supply chain nodes to evaluate the network risk value, the specific calculation formula is as follows:

$$R(t)=\sum_{k=1}^{m}V_kR_k(t) \tag{15}$$

where V_k represents the weight of node k of the water resource supply chain. The advantages of cloud technology in risk assessment of the correlation between nodes of water supply chain are as follows: It not only takes into account the partial similarity between the cloud droplets in the cloud model, but also takes into account the overall similarity between the cloud model shapes [21]. So that the evaluation model has a high accuracy, but also make the model can be generalized.

4. Experimental results and analysis

In order to prove the detection performance of the water resource supply risk assessment method proposed in this paper, it needs to be verified by relevant simulation experiments. The experimental hardware device is Intel®4 Core 2.5GHzCPU, 8GRAM, Windows10, built an experimental simulation platform for water supply risk assessment under the MATLAB platform. Experimental data from the KDDCUP99 data set are obtained from 8-week water supply data packets, each record contains 40 water supply characteristics. To illustrate the feasibility of the supply risk assessment model for the water resources supply chain of the South-to-North Water Diversion Project. The selection of Gim et al. [3] proposed based on the modified VAR water multiple water supply chain risk assessment methods and Zhao et al. [4] are proposed based on fault tree and Bayesian Network of water supply chain risk assessment methods as experiment contrast. Contrast with the proposed method.

4.1. Comparison of risk identification rates between different methods

The risk recognition rate of the test method is shown in Fig. 2.

The traditional methods in Fig. 2 are the risk assessment research method of multiple water resources supply chain based on improved VAR proposed in Gim et al. [3] and the risk assessment method of water resources supply chain based on accident tree and Bayesian Network proposed in Zhao et al. [4]. The analysis of Fig. 2 shows that, in 120 experiments of this method, the highest recognition rate of the proposed method is about 98%, and the overall risk recognition rate is between 80% and 100%. In 120 experiments with traditional methods, the highest recognition rate of water resource supply is 75%, and the overall risk recognition rate is between 70% and 75%. The comparison

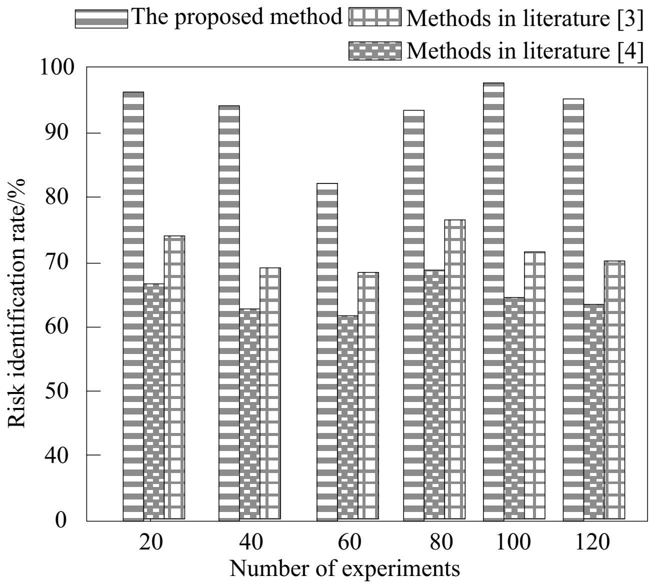

Fig. 2. Different methods of risk identification test results.

shows that the recognition rate of supply risk of the water resource supply chain is relatively high.

4.2. Comparison of risk identification fitting degree between different methods

Based on risk identification test, to identify the risk of probability prediction, test probability prediction results and the actual results of the fitting. The test results are shown in Fig. 3.

The traditional method in Fig. 3 is the risk assessment research method of multiple water resources supply chain based on improved VAR proposed in Gim et al. [3] and the risk assessment method of water resources supply chain based on accident tree and Bayesian Network proposed in Zhao et al. [4]. In 120 experiments using this method, the degree of fitting between the predicted results and the actual results varies from 85% to 100%. In 120 experiments with the traditional method, the degree of fitting between the predicted results and the actual results varies from 40% to 70%. A comparison of experimental data is available. The probabilistic prediction results of water resource replenishment risk with the method in this paper have a high fitting degree with the actual results, which verifies the feasibility of the model in this paper.

4.3. Extraction and comparison of water resource replenishment characteristics by different methods

Respectively using this design model and Gim et al. [3], the method of Zhao et al. [4] water supply risk assessment process of the water supply feature extraction accuracy experiments. Under different experimental times, the extraction accuracy of water resource recharge features of different methods was compared, and the comparison results were shown in Fig. 4.

The analysis of Fig. 4 shows that, under the condition of the same number of experiments, the accuracy of feature

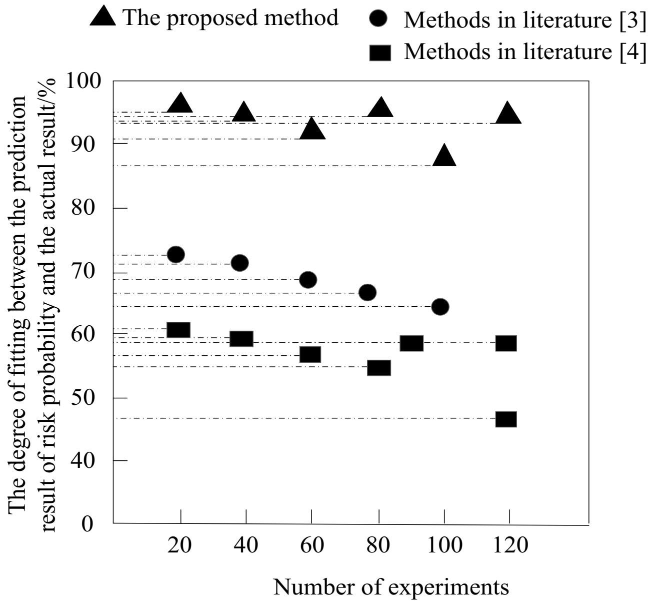

Fig. 3. Different methods of risk probability prediction results and the actual results of the fitting.

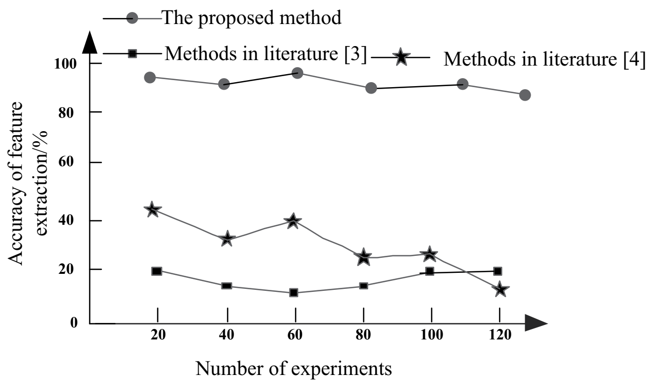

Fig. 4. Different methods of feature extraction accuracy.

extraction is much higher than that of traditional methods. And with the increasing number of experiments, the advantages of this method are still obvious. On the whole, the average accuracy of water resource recharge feature extraction using this method is about 95%, while the average accuracy of traditional method is about 20%.

4.4. Comparison of omission rate of different methods

The improved model and Gim et al. [3] method and Zhao et al. [4] were respectively used to carry out the water resource supply risk assessment experiments. In different experimental times, the extraction accuracy of water resource recharge features of the two different methods was compared, and the comparison results are shown in Fig. 5.

The analysis of Fig. 5 shows that, under the condition of the same number of experiments, the risk omission rate is much higher than that of the traditional method when using this method to predict the water resource supply risk. And with the increasing number of experiments, the advantages

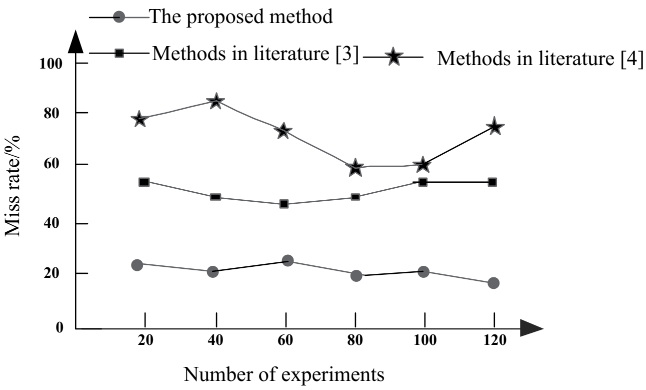

Fig. 5. Miss rate comparison of different methods of risk assessment.

of this method are obvious. On the whole, the average missed detection rate of water resource replenishment risk assessment using this method is about 20%. The traditional method is about 40%–80%, which indicates that the method in this paper has a small rate of omission and is not easy to occur.

5. Conclusions

Aiming at the drawbacks in the supply risk assessment process of the water resources supply chain of the South-to-North Water Diversion Project, a supply risk assessment model was designed. PCA technology was used to extract the water resource supply information characteristics of the South-to-North water diversion water supply chain and eliminate the collinearity among various water resource supply characteristic variables. This step can effectively improve the accuracy of risk assessment. To obtain the correlation between nodes of the water supply chain and construct the water resource supply risk assessment model of the South-to-North Water Diversion Project.

The simulation results show that: The model designed in this paper has a high-risk recognition rate, and the fitting degree between the prediction results and the actual results is within the range of 85%–100%. Moreover, the accuracy of risk assessment is about 95%, and the rate of missed detection is about 20%, which has obvious application advantages compared with traditional methods.

However, the complex environmental fitness of the model cannot be verified because the design model described in this paper does not take into account the adaptability condition. In order to obtain better research results, this entry point is the first problem to be further solved in the future.

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