

Construction quality risk management of projects on the basis of rough set and neural network

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Abstract

Construction quality associated with the life of construction enterprises. Risk assessment of construction quality referred to a comprehensive evaluation of the degree of risk confronting construction units during the construction process. Construction units provide a decision-making basis for employers and supervisors, who considered the evaluations of construction quality and accidents in their decisions. The risk factors of construction project quality were classified into personal risk and material risk and machinery and equipment risk and method risk and environment risk. On the basis of these factors, we constructed an index system of project construction quality risk. The risk evaluation model of project construction quality was constructed on the basis of rough sets and neural networks. Finally, a case study residential building projects in the Ganzhou Development Zone and research tools of Rosetta based on rough sets and MATLAB7.0 based on neural networks were used to test model accuracy and reason ability. Empirical results showed that the model has great practical significance.

Keywords: construction quality risk assessment, projects, rough set, neural networks

1 Introduction

The rapid development of the national economy has caused project constructions to exhibit a growing trend. However, such projects are confronted with numerous sun foreseen interference factors during the construction process. These factors give rise to the requirement for project participants to discuss and consider various risks. Uncontrolled risks may pose serious problems to the whole project. Thus, improving the risk management level of project construction quality is a task that project managers must focus on.

The construction quality risk assessment of a project is the most effective management means to improve construction quality and to avoid construction quality accidents. Such assessment is the core link of project quality risk management.

Construction quality risk assessments have yet to establish a unified and comprehensive index system. The lack of effective data sources causes a low construction quality risk management level of a project, such that the project manager is believed to possess a generally weak risk consciousness. These issues must be mitigated as continuous economic globalization has made international competition increasingly fierce.

Given this background, this study employs modern project management theory and incorporates advanced foreign project quality risk management experiences. Considering the inherent nature of construction quality risk management of a project, we propose project quality risk management methods that our suitable for the Chinese construction industry.

The risk factors that influence construction project quality are identified as personal risk, material risk, machinery and equipment risk, method risk, and environment risk. The index system of project construction quality risk was constructed, and the risk evaluation model of project construction quality was established on the basis of rough sets and neural networks.

2 Status of foreign and domestic research

2.1 STATUS OF FOREIGN RESEARCH

Risk management is a rapidly developing integrated discipline. The emergence of risk management can be traced back to ancient human productive labor. As societies constantly progress, enterprises encounter all types of risk during the development process. To help enterprises survive and grow, risk management, as an important part of enterprise management, was developed to reduce the risk of loss. Risk management has been employed to deal with risks, to facilitate stabilization after the occurrence of a financial risk, and to achieve the effective use of enterprise resources.

Early foreign research on risk management has been limited to enterprise risk. However, with the increase in construction engineering projects, the frequency of engineering project risk occurrence and the rapid development of engineering project management technology, risk management has been included in the scope of project management. Thus, project risk management was established.

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Many uncertain factors in project construction may cause projects to fail and economic interests to be lost. Based on the experiences of and lessons from researchers abroad, the quality of project risk management has gradually been enhanced. With the continuous development of engineering project construction, project quality risk management has improved. Since the 1960s, foreign project quality risk management has become increasingly professional, systematic, and scientific, employing professional research personnel and specialized research institutions to address future adverse events.

Project quality risk assessment research abroad has various characteristics. First, most project quality risk research scholars focused on the technical level, including project decision analysis, coping strategies, project risks, and international economic research. Second, with the rapid development and wide application of computer technology, calculation methods have become more accurate and foolproof. The combination of qualitative and quantitative risk analysis methods was the primary approach employed in project quality risk management research [1-5].

2.2 STATUS OF DOMESTIC RESEARCH

Although domestic risk management started late, risk management has been widely used in project construction, finance, real estate development, and other fields. Many studies have been conducted on project quality risk, and research results have been beneficial. It has analyzed the causes of engineering quality accidents in detail and used the theory of project management system to discuss how to improve project quality further [6]. It combined fuzzy mathematics and analytic hierarchy process, constructed a quality risk evaluation index system for housing construction project construction, and proposed the housing construction project construction quality risk assessment model [7]. Additionally, it proposed a project risk evaluation model based on cost, time, and quality. They combined the analytic hierarchy process and fuzzy comprehensive evaluation method in a detailed study on risk factors, including cost, time, and quality of influence [8]. It believed that project quality risk exists throughout the whole construction period of a project, such that measures should be implemented at all stages of project quality risk assessment [9]. Steps must be taken to reduce the quality of engineering project risks. Further more, it used analyses of natural risk, material risk, and construction risk to establish a risk evaluation index system of quality and then evaluated the quality of a project risk with the use of the fuzzy evaluation method [10]. It established a project quality risk evaluation index system based on the cause of project quality risk factors, evaluated the quality of the project risk using the fuzzy comprehensive evaluation method, and established a quality risk response according to evaluation results [11]. Finally, it established a project quality risk management model based on Bayesian network and conducted risk identification, risk evaluation,

risk diagnosis, and risk control and achieved results using the project quality risk model [12].

3 Identification of construction project quality risk factors

Project construction can be characterized as long-term, outdoors, and large-scale, such that the process is easily influenced by natural and social conditions. Combining the construction technology of production and that of liquid variability and other characteristics reveals that numerous factors affect project quality. These factors may result in construction quality accidents. Applying the principles of system engineering and the Delphi method to a large number of construction quality accident investigations and data analyses, we identify the main factors influencing engineering project construction quality as man, materials, method, mechanical, and environment. These factors are called 4M1E.

Under normal circumstances, most project construction quality accidents are caused by factors related to 4M1E, such that identifying and analyzing these factors can ensure that the project runs smoothly with high construction quality.

3.1 THE HUMAN FACTORS

Man refers to the project managers, leaders, and operators involved in the project. Man directly and indirectly affects construction quality because of personal, ideological, cultural, business, and quality attributes, among others.

3.2 THE MATERIAL FACTOR

Material refers to raw materials, auxiliary materials, semi-finished products, components, and fittings, among others. The quality of the material determines the level of project quality. If the material quality does not meet the requirements, meeting the project quality standards is impossible.

3.3 MECHANICAL FACTORS

Mechanical, machinery, and equipment generally refer to construction equipment, construction machinery, and construction tools and instruments. With the continuous expansion of project scale, machinery and equipment have become indispensable parts of a facility.

3.4 THE FACTORS OF METHOD

Methods refer to the employed technology programs, processes, construction designs, and construction technology measures during the construction phase. To some extent, choosing the construction program reasonably and correctly directly affects project quality control.

3.5 ENVIRONMENTAL FACTORS

Environmental factors associated with the construction quality of a project include three major factors: the scene of the natural environment, construction quality management, and engineering labor work environment factors. The environmental factors change constantly during construction phase, such that these factors directly affect the project.

4 Quality risk assessment of construction project on the basis of rough sets and neural networks

4.1 CONSTRUCTION OF THE INDEX SYSTEM

Based on the above analysis of the risk factors affecting the quality of the construction phase and combined with the principles and basis of indicators, the quality of risk evaluation index system of the construction phase of a project was built, as shown in Table 1.

TABLE 1 Project quality risk assessment index system of construction stage

Evaluation index	First Indicators	Number	Second indicators	Degrade				
				I	II	III	IV	V
U	U ₁ Human factor	1	U ₁₁ Degree of compliance manager qualifications					
		2	U ₁₂ Degree of operator qualification standards					
	U ₂ Material factors	3	U ₂₁ Standards of the material quality					
		4	U ₂₂ Soundness of the material properties					
	U ₃ Mechanical factors	5	U ₃₁ Degree of compliance with the quality of machinery and equipment					
		6	U ₃₂ Rationality of machinery and equipment selection					
		7	U ₃₃ Standardized machine operators					
	U ₄ Method factors	8	U ₄₁ The rationality of the construction technology program					
		9	U ₄₂ Construction technology and construction methods of the advanced and rationality					
		10	U ₄₃ Rationality of construction detecting methods and construction technical measures					
	U ₅ Environmental factors	11	U ₅₁ Natural environment of construction site					
		12	U ₅₂ Quality assurance system of construction unit					
		13	U ₅₃ Quality management system of construction unit					
		14	U ₅₄ Technical and economic conditions					
		15	U ₅₅ Construction work environment					

Description: I very good, II good, III fair, IV poor, V very poor.

4.2 PROJECT CONSTRUCTION QUALITY RISK ASSESSMENT ON THE BASIS OF ROUGH SET AND NEURAL NETWORKS

This study proposes a neural network risk assessment method using a combination of weak coupling methods, namely, rough sets and neural networks. With rough theory as a neural network front-end system, the sample data input of the neural network is first simplified. The simplified sample data are then imported to the neural network, and the mature classification model is produced through training. Finally, the quality of the risk level of the project is evaluated on the basis of the output of the classification model network, which can provide an objective basis for the decision-making of project managers.

Given the basic idea of rough set and neural network risk assessment methods and the actual characteristics of the construction quality risk assessment, a quality risk assessment model of construction projects can be established on the basis of neural networks and rough sets. The basic idea is as follows:

1) Collecting data: by collecting detailed information on the construction site of a project, possible accidents caused by the project construction quality risk factors can be identified;

- 2) Data processing: discrete data processing is performed;
- 3) Identified the smallest risk factor set of construction quality of projects: by the means of the theory of rough set attribute reduction of the construction quality of construction project risk evaluation index system, the smallest project quality indicators of the risk factor set can be identified;
- 4) Data training and establishing network model: training of the neural network data can aid in establishing an appropriate network model;
- 5) Testing the network model: the network model is tested by using specific project data, which are compared with the actual risk value;
- 6) Calculating the risk assessment result: the quality risk evaluation index data are used as input to the project construction to be evaluated. The value risk assessment objectives are then derived.

5 Empirical analysis

This study takes the characteristics of project construction as a foundation to establish the quality of the risk assessment model of construction on the basis of rough sets and neural networks. Data collected in the field will be applied and tested.

5.1 DATA COLLECTION

Data were collected at the Ganzhou Development Zone, a high-rise residential building project with two underground floors, 11 floors above ground, and underground parking lot. The project has a total gross floor area of 3,802m², a building height of 34.2m, take-situ concrete construction, columns, beams, plates, and concrete strength grade of C30. The project was constructed during summer. The construction site has various facilities, convenient transportation, and good work environment. In accordance with the construction process established in this study and the construction quality of the project risk evaluation index system, we selected the high-rise residential building project layer cast concrete columns for this study.

5.2 CALCULATING THE INDEX WEIGHT AND FORMATION THE SAMPLES SET OF THE RISK FACTORS

Based on the collected data, the number of samples in this article does not meet the required number of samples for the model. Thus, 14 projects of similar nature were added to the sample data for analysis. However, these projects are not listed here.

These projects were in the construction phase. In-site concrete columns and quality risk assessment indicators for each construction stage sample are presented in the Table 2. The symbols “” represent the level of the actual situation, which can be “very good, good, fair, poor, or very poor.”

TABLE 2 Actual situation for each sample indicator

Sample	U ₁		U ₂		U ₃			U ₄			U ₅				
	U ₁₁	U ₁₂	U ₂₁	U ₂₂	U ₃₁	U ₃₂	U ₃₃	U ₄₁	U ₄₂	U ₄₃	U ₅₁	U ₅₂	U ₅₃	U ₅₄	U ₅₅
1	I	II	II	II	II	III	II	II	II	III	III	II	II	I	II
2	II	II	II	II	III	II	III	II	III	III	II	II	II	II	III
3	II	II	II	II	III	III	III	II	III	II	II	II	II	III	IV
4	II	III	II	II	III	II	II	II	II	II	III	II	II	III	III
5	I	II	III	III	III	III	III	II	II	II	IV	II	II	III	IV
6	II	IV	II	II	III	III	II	I	II	II	II	III	III	III	II
7	III	III	III	III	I	II	II	I	II	II	II	II	II	III	II
8	II	I	II	II	III	III	III	II	II	III	II	II	II	II	I
9	II	IV	III	III	II	III	III	II	II	II	I	II	II	II	I
10	III	III	III	III	II	III	III	II	II	III	IV	III	III	III	IV
11	II	III	II	II	II	I	I	II	III	III	II	III	III	II	III
12	I	II	II	II	III	III	III	III	II	II	III	I	I	II	III
13	II	III	II	II	II	III	III	II	II	III	II	II	II	IV	II
14	II	I	III	III	II	II	II	I	II	III	II	II	II	II	III
15	II	II	II	II	III	III	II	I	II	II	II	III	III	II	II

On the basis of the original data, we used the AHP-Fuzzy evaluation method was used to calculate the right weight of each site and the quality of the risk of each sample. The risk sample sets of neural networks were then reduced.

First, we determine the weight of paper using AHP. Eight staff members with extensive experience are employed to compare the risk factors in the construction site. These staff members include project managers, construction workers, technicians, security staff, chief supervision engineers, quality engineers, and so on. The judgment matrix is then established. The U₁–U₅ layer-right weight set is: U = (0.271,0.311,0.236,0.104,0.079). Other indexes are calculated in the same manner as the criterion level U₁–U₅. The final weight is determined as follows: U₁ = (0.500, 0.500), U₂ = (0.500, 0.500), U₃ = (0.333, 0.333, 0.333), U₄ = (0.489, 0.291, 0.220) and U₅ = (0.333, 0.111, 0.111, 0.333, 0.111).

Second, each sample of construction quality risk is calculated using the fuzzy comprehensive evaluation method. Similarly, the quality of the risk can be drawn from all the construction site samples, as shown in Table 3.

TABLE 3 Construction quality risk assessment of each site samples

Sample	Risk	Sample	Risk	Sample	Risk
1	0.163	6	0.369	11	0.317
2	0.236	7	0.335	12	0.212
3	0.289	8	0.218	13	0.352
4	0.258	9	0.343	14	0.326
5	0.392	10	0.421	15	0.265

The risk of sample sets of the neural networks was determined, from which the former 10 sample sets were selected for learning neural network training, and the other five sample sets were selected as the test samples for the neural network.

5.3 CONSTRUCTION QUALITY RISK ASSESSMENT PROCESS OF PROJECTS BASED ON ROUGH SET AND NEURAL NETWORK

Construction project quality risk assessment processes were established on the basis of rough set sand neural networks. The index system was simplified with the ge-

netic algorithms in Rosetta software, and the discrete set of post-processing was incorporated into the calculation

in the software. The set of simplified data is reduced by the software, as shown in Figure 1.

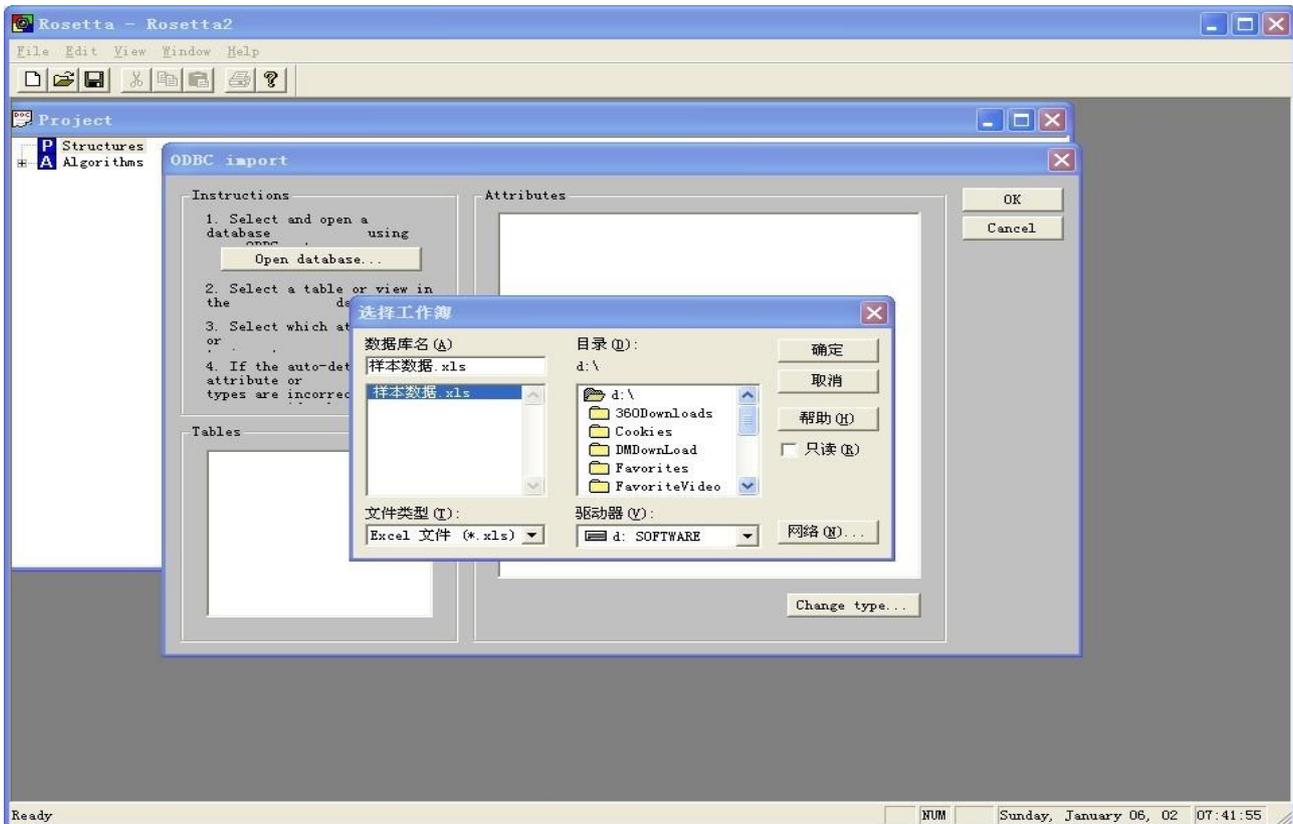


FIGURE1 Rosetta import data manipulation

In this study, considering the support and reduction lengths of the two factors, we selected an optimal set of conditions as follows: $U = (U_{11}, U_{12}, U_{21}, U_{22}, U_{31}, U_{33}, U_{41}, U_{54})$.

MATLAB7.0 was then used to define, train, and test a back propagation BP neural network. The specific steps are as follows:

Creation of the input and output data. Ten former sets of sample data were selected as the training sample set. The input matrix has a total of 10 lines, representing 10 samples, and a total of eight rows, with eight data points for each row in each sample. The eight data points represent the value attribute of $U_{11}, U_{12}, U_{21}, U_{22}, U_{31}, U_{33}, U_{41}, U_{54}$. The output matrix t has a total of 10 rows, which represent the value of quality risk attribute in the construction of a project.

Creation of a BP neural network. The specific statement is as follows: `net=newff([0 1; 0 1; 0 1; 0 1; 0 1; 0 1; 0 1; 0 1; 0 1; 0 1],[17,1],{'tansig','tansig'},'traingdx')`. The range description of each value input unit from the first parameter input is [0,1]. The second parameter [17,1] describes node values of 17 and 1 in the hidden layer and output layer, respectively. The third parameter {'tansig',

'tansig'} illustrates that the hidden layer and output layer transfer functions are all tansig functions. The fourth parameter 'traingdx' illustrates the training function selected for the function of neural networks.

Setting of training parameters. The specific statement is as follows:

```
net.TrainParam.show=50
net.trainParam.lr = 0.09
net.trainParam.epochs = 10000
net.trainParam.goal = 0.001
```

Start training network. Specific statement is follows as:

```
[net, tr]=train(net, p', t')
```

Inspection of data. The five remaining sets of data are used for testing .pt is the testing matrix that has a total of five lines and eight rows. The specific statement is as follows:

```
a=sim (net, pt')
```

Each of the above statements are used as input for MATLAB7.0 software to obtain the final training results as shown in Figure 2.

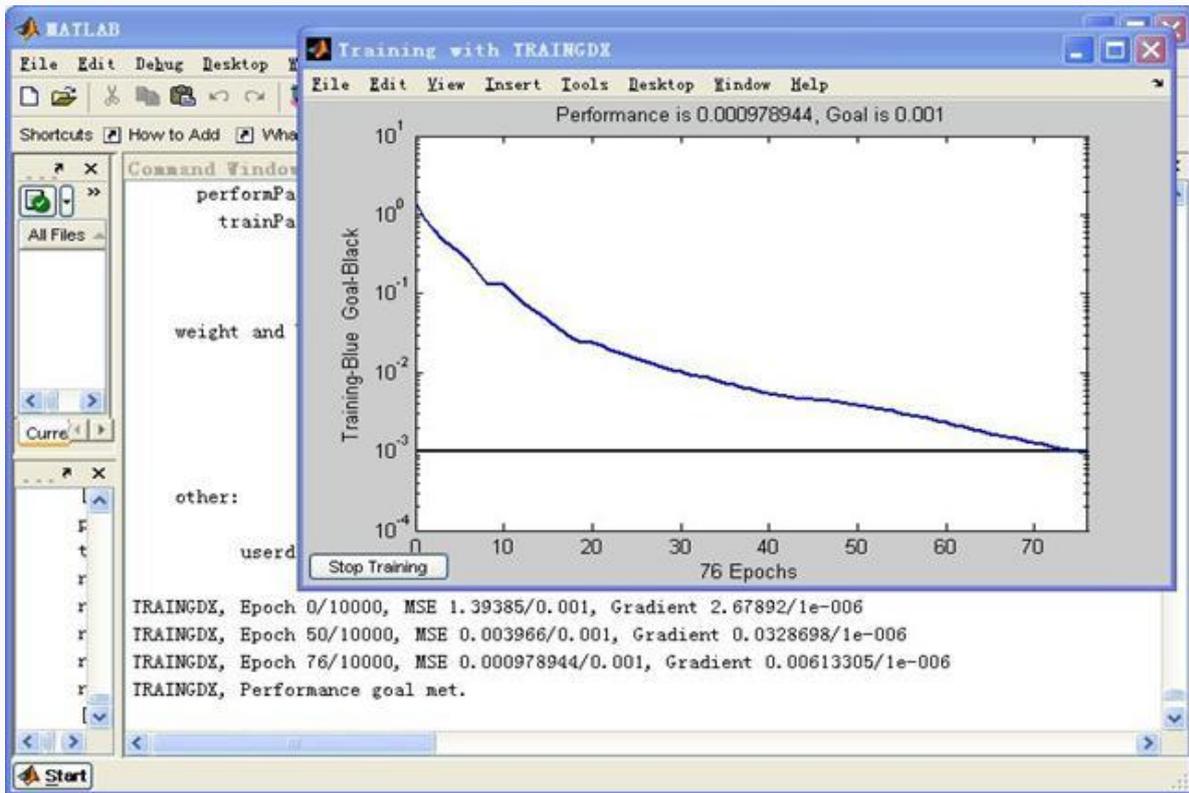


FIGURE 2 Training error curve

As shown in Figure 2, after 76 iterations through the training, the accuracy of the model is less than 0.001. The remaining five groups of samples were used to test the accuracy of the neural network model. The result of the command `a = sim (net, pt')` is as follows:

```
a=sim(net, pt')
a =0.3204 0.2221 0.3433 0.4069          0.2747
```

The results of the output show that the actual output risk values of sample sites 11 to 15 (i.e., the risk value) were 0.3204, 0.2221, 0.3433, 0.4069, and 0.2747, respectively. The quality risks of construction from the model of site evaluation samples 11 to 15 were smaller, smaller, smaller and smaller, general, and smaller. The results of the model are then compared with the actual value of the output. The difference between the absolute value of the error rate of the output value and the true value is divided by the actual value, as shown in Table 4.

TABEL 4 Output samples

Sample	11	12	13	14	15
True Value	0.317	0.212	0.352	0.326	0.265
Output Value	0.3204	0.2221	0.3433	0.4069	0.2747
Error rate	1.07%	4.76%	2.47%	24.82%	3.66%

Table 4 shows that the actual output value and the true value of the model are broadly consistent, indicating that the quality risk assessment of the accuracy rate after training and learning of the sample set in project construction is became higher, which is in line with the actual situation of the project. Most error rates were acceptable. The error rate of sample site13is relatively high. However, the average error rate of the five groups of samples was 7.356%, indicating that a higher evaluation model training accuracy results in a more ideal the evaluation.

6 Conclusion

6.1 ESTABLISHING CONSTRUCTION QUALITY RISK ASSESSMENT MAODEL OF PROJECTS ON THE BASIS OF ROUGH SET AND NEURAL NETWORKS

Neural network software programs (e. g., Rosetta and MATLAB7.0) were used as basic research tools in this study. The quality risk assessment model was tested through empirical analysis on the basis of rough sets and neural networks. The results of the empirical analysis show that higher accuracy of model training results in a more ideal evaluation.

6.2 THE INNOVATIVE APPLICATION OF ROUGH SET TO NEURAL NETWORK IN CONSTRUCTION QUALITY RISK ASSESMENT

Rough set theory knowledge was taken as a neural network front-end system, and the input data were preprocessed and compared with those derived from the traditional BP neural network, which effectively simplified the complex structure of the neural network, shortened the neural network training

time, and improved the accuracy of generalization and training of the neural network.

Rough set and neural network risk assessment model can accurately simulate the decision-making process of construction quality experts on risk assessment of the project, thus artificially reducing uncertainties in the risk assessment process and effectively combining knowledge acquisition, functional expert systems, and fuzzy reasoning.

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