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Risk assessment method of human resources outsourcing based on risk matrix

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Abstract: In order to reduce the error of risk assessment and improve the correlation of risk indicators, a risk assessment method of human resource outsourcing based on the risk matrix method is proposed. First, determine the risk indicators of human resource outsourcing, use the rough set theory to determine the indiscernibility of the evaluation indicators, and use F-score to calculate the risk evaluation indicators and their information gain. Then, build a risk matrix coordinate chart to identify outsourcing risk factors, calculate the probability of outsourcing risk occurrence using the conditional random field joint probability formula, and build a risk assessment model through the risk matrix method to complete the risk assessment. The experimental results show that the evaluation error of the proposed method is always less than 2%, and the maximum correlation coefficient is close to 1, which verifies the effectiveness of the method.

Keywords: risk matrix method; human resources; outsourcing risk; f-score; information gain; joint probability of conditional random fields.

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1 Introduction

Human resource outsourcing can reduce the daily workload of enterprises and enable managers to focus more on the development of enterprises. It can be said that this mode is the key link to achieve the enterprise development and long-term strategic objectives (Yazdani et al., 2021; Boudlaie et al., 2022; Lv, 2021). However, in the process of human resources outsourcing, it is necessary to inspect the outsourcing company's ability level. If this important event is entrusted to a human resources company with poor ability, combined with cultural differences, cognitive ability and other factors, it will seriously affect the quality of outsourcing. This will cause the enterprise to bear a certain financial

loss risk, which will seriously affect the future development of the enterprise (Westerman et al., 2021; Tian et al., 2020). Therefore, it is necessary to evaluate the risks in human resource outsourcing and prevent them according to the evaluation results. Researchers have done a lot of research on risks in outsourcing, and have made some achievements.

Zhang et al. (2021) proposed a risk assessment method for enterprise human resource outsourcing with the help of probability language set. In the study of this method, the instability of outsourcing risk is analysed many times, and a new expert evaluation method is determined according to the set of probability languages. Set different language sets to different probability values, and determine the direct relationship between risks according to the preference of factors in the language set. Conduct integral analysis on the factors that have more serious impact, effectively evaluate the risk factors, determine the evaluation results of outsourcing risks, and achieve effective evaluation research. The experimental results show that the method is more accurate in determining the risk relationship, but the evaluation data is less, and there is a certain degree of one-sided. Zhang and Wang (2020) proposed a risk assessment method of human resource outsourcing service based on heterogeneous relationship. Based on the existing research methods, this method determines a social relationship network, analyses the status of human resources at different stages, determines the risks of different social human resources relationship structures, conducts a semi quantitative analysis of outsourcing risks, controls the risks of outsourcing through three stages, connects relevant informal management risks, determines the risk assessment method, and realises the outsourcing risk assessment. The experimental results show that this method has many risk factors and high reliability of the assessment results, but the assessment process is more complex and the assessment time is longer. In addition, some scholars put forward a SPA-based dynamic evaluation method for human resource outsourcing risk. On the basis of outsourcing risk analysis, combined with the implementation process of human resource outsourcing, they built a human resource outsourcing risk evaluation index system. Aiming at the uncertainty and dynamics of outsourcing risk evaluation process, they used set pair analysis quaternion and Markov chain to build a human resource outsourcing risk evaluation model, realise risk assessment of human resource outsourcing. The experimental results show that this method can mine more hidden information, and it is feasible and effective, but the accuracy of the evaluation results is not high, and the correlation between risk indicators is low.

On the basis of the above risk assessment methods of enterprise human resource outsourcing, this paper designs a risk matrix-based risk assessment method of enterprise human resource outsourcing. By analysing the driving factors of enterprise human resource outsourcing, determining the key influencing factors of outsourcing risk, introducing the risk matrix, determining the weight of risk factors, etc. the design of enterprise human resource outsourcing risk assessment method is completed. The main technical route of this method design is:

Step 1 Determine the driving factors of enterprise human resource outsourcing through analysing the current situation of enterprise human resource development, mainly including external driving factors and internal driving factors; according to the different participants in the outsourcing process, the enterprise human resources outsourcing risk indicators are determined as: enterprise risk indicators, project contractor risk indicators, employee risk indicators and outsourcing environmental factor risks; conduct outsourcing risk assessment

based on the determined risk indicators to improve the correlation coefficient of risk indicators.

- Step 2 Use the rough set theory to determine the indiscernibility of the evaluation indicators, use F-score to calculate the importance of the risk indicators, calculate the information gain of the risk indicators, complete the pre-processing of the HR outsourcing risk indicators, and reduce the error of outsourcing risk evaluation.
- Step 3 Build a risk matrix coordinate map to identify outsourcing risk factors; calculate the entropy value of the risk factors to determine their importance, determine the influence degree of the factors in the form of a binary system, calculate the probability of outsourcing risk occurrence with the conditional random field joint probability formula, and finally build a risk assessment model with the risk matrix method to complete the risk assessment.
- Step 4 Take outsourcing risk evaluation error, risk index correlation coefficient and evaluation time consumption as experimental indicators to conduct experimental analysis.

2 Determination of enterprise human resource outsourcing driving factors and risk assessment indicators

2.1 Analysis on the driving factors of human resources outsourcing in enterprises

The social and economic activities of enterprises are all for profit, and profit is not only based on the profit of enterprise products and services. Any enterprise takes costs and benefits into account in its production and operation. In the process of realising enterprise profitability, it is necessary to optimise the allocation of multiple resources in the enterprise (Zinovyeva et al., 2021). When the utilisation efficiency of internal resources is not high, enterprises can allocate resources through outsourcing. In this process, it is first necessary to identify the main driving forces of enterprise human resources outsourcing. The driving forces of enterprise human resource outsourcing are mainly divided into external driving forces and internal driving forces. The specific driving factors are shown in Figure 1.

It can be seen from Figure 1 that the main driving factors of human resource outsourcing include internal factors and external factors.

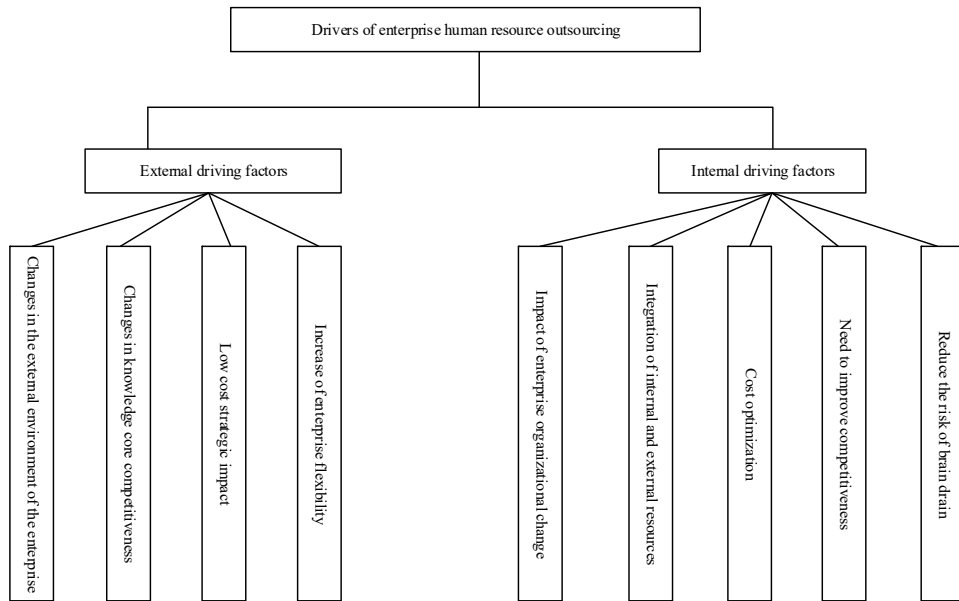
2.1.1 External drivers

In the external driving factors of enterprise human resources outsourcing, they mainly include changes in the enterprise's external environment, changes in knowledge core competitiveness, the impact of low-cost strategy and the increase of enterprise flexibility.

The change of the external environment of the enterprise refers to the speed of information transmission and the explosive growth of the amount of information, resulting in certain changes in the consumer groups of the enterprise. On the basis of traditional enterprise consumption, the new external consumption environment

undoubtedly increases the cost of enterprise operation. The potential external environment will lead to business risks (Marin et al., 2022). Therefore, the outsourcing of human resources in enterprise management can enhance the competitiveness of enterprises, reduce operating costs, and adapt to the changing external enterprise environment with the help of talents.

Figure 1 Schematic diagram of driving factors of enterprise human resources



The influence of knowledge core competitiveness is already very obvious. In the context of enterprise development and resource globalisation, talents are the key core competitiveness of enterprise competition. Enterprise competitors are limited, but the strength of talents is unlimited. Enterprise development needs to focus on human resources, and only talents can innovate and develop.

The low-cost market strategy faced by enterprises has become an unavoidable topic for global enterprises. Cost control has always been the consensus of enterprise development, especially when the enterprise economy is facing winter, it is undoubtedly an effective way to continuously obtain and occupy the market by reducing costs (Zhu et al., 2022). Therefore, the emergence of enterprise human resource outsourcing services can provide enterprises with highly talented talents and reduce the cost of talents.

The increase of enterprise flexibility is also the key to affect the outsourcing of human resources. There are many business transactions between enterprises, and the marginalisation of their own organisations is becoming more and more vague, leading to the traditional human resource management model of enterprises can not adapt to the new environment. Therefore, it is an effective way to improve service quality through outsourcing human resource management.

2.1.2 Internal drivers

Among the internal driving factors of enterprise human resource outsourcing, they mainly include the impact of organisational change, the demand for integration of internal and external resources, the need to achieve cost optimisation, the need to improve competitiveness and reduce the risk of brain drain.

Among the influencing factors of organisational change, the development of the enterprise requires the human resources department to participate in the decision-making of the enterprise, integrate the human resources department and the market management department, and transform them into a key department for decision-making suggestions. Enterprise managers want to help decision-making through the human resources department, so they outsource human resources.

In the demand for integration of internal and external resources, the work form of the human resources department is traditional. By outsourcing it, the outsourcing organisation can use its high-quality professional capabilities and services to provide an effective management system, which can promote the transformation of the core work of the human resources organisation and save the cost of employment.

In order to achieve cost optimisation, enterprises need to improve enterprise management, which requires the selection of professional managers. In this process, the cost of employment will increase, which may lead to low corporate efficiency. Outsourcing this service can reduce costs and achieve optimal cost (Jia et al., 2020).

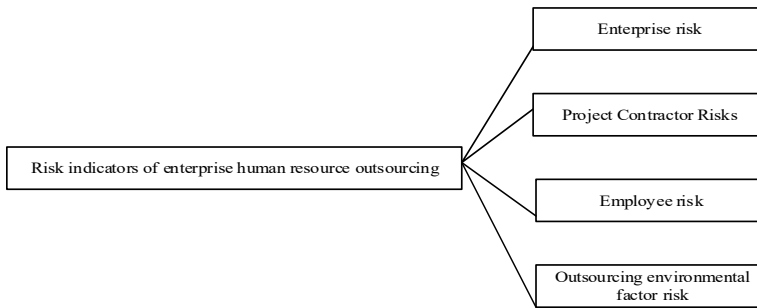
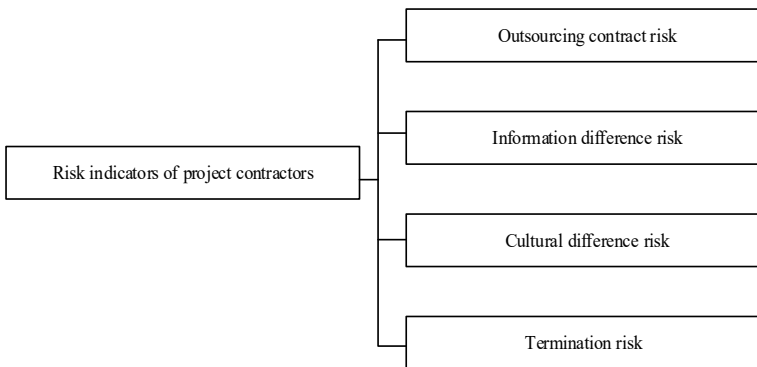
In the need of improving competitiveness, the sufficiency of core talents in the sustainable development of enterprises is the key to the stable production of the entire enterprise production chain. It is necessary to give consideration to talents and costs, and also use talents in the business of enterprise survival and development to achieve certain profits.

In reducing the risk of brain drain, due to the continuous improvement of the enterprise's human labour market, the enterprise's employment model has also been better reformed. In these experienced human resource management, they have a certain control ability in dealing with the risk of brain drain and other risks.

2.2 Determination of enterprise human resource outsourcing risk indicators

According to the above determined driving factors of enterprise human resource outsourcing, in order to improve the effectiveness of enterprise human resource outsourcing risk assessment, it is necessary to determine the key indicators of risk assessment, and deal with these indicators to improve the reliability of risk assessment. In the enterprise human resources outsourcing risk assessment, according to the different participants in the outsourcing process, the enterprise human resources outsourcing risk indicators are determined as: enterprise risk indicators, project contractor risk indicators, employee risk indicators and outsourcing environmental factor risks. The specific enterprise human resources outsourcing risk indicators are shown in Figure 2.

Enterprise risk indicators mainly include human resource management decision-making risk, adverse selection risk, internal control risk, contract risk, cost control risk, management risk, information disclosure risk, etc. Risk indicators of project contractors are shown in Figure 3.

Figure 2 Schematic diagram of enterprise human resource outsourcing risk indicators**Figure 3** Schematic diagram of project contractor's risk indicators

Employee risk indicators mainly include employee self-awareness and control ability. In the enterprise human resource management, the reflection of employees' self-awareness and ability is very critical, which affects the future development of the enterprise. Therefore, this indicator is selected for the evaluation study.

Outsourcing environmental factor risk indicators mainly refer to the social environment, economic and technological environment and outsourcing risks faced by the market. These factors affect the quality of human resource outsourcing services.

2.3 Pre processing of enterprise human resource outsourcing risk assessment indicators

Because the evaluation index of human resource outsourcing risk is relatively abstract, it is difficult to study with a kind of actual data. In order to reduce the difficulty of risk assessment, the indicators determined in the above chapters will be uniformly pre-treated in this chapter to lay a foundation for subsequent assessment.

In the pre-processing of enterprise human resource outsourcing risk assessment indicators, it is necessary to identify these qualitative changes. In this paper, the indiscernibility of these evaluation indicators is divided into several disjoint equivalent indicators in the form of universe by virtue of rough set theory (Shi et al., 2022; Lin et al., 2022). Traditional methods need to process all data or indicators in the pre-processing of risk assessment indicators, which will consume a lot of time. One of the main advantages

of rough set theory is that it does not need any preparatory or relevant data information, such as probability distribution in statistics, or membership or probability value in fuzzy set theory. Therefore, compared with traditional methods, it is conducive to improving the efficiency of risk assessment. Assume that the information system of enterprise human resource outsourcing risk assessment indicators is:

$$Info = (A, B) \quad (1)$$

In formula (1), A represents the finite theory field in the risk assessment index information system, and B represents the evaluation index as a finite set composed of features. Assuming that C_a represents the set of features of each evaluation index in this theoretical field, there is the following equivalent relationship for the characteristics of any evaluation index, that is:

$$D(x) = \{x, y \in A \mid C_a \in x, y\} \quad (2)$$

In formula (2), $D(x)$ represents the characteristic equivalence relationship expression of the evaluation index, while x and y represent the different characteristic factors of the evaluation index, respectively.

According to the characteristic equivalence relationship of the determined evaluation indicators, the universe of HR outsourcing risk indicators can be determined as:

$$A/D(x) = \{x \in X : A/D(x)\} \quad (3)$$

In formula (3), X represents the indistinguishable coefficient of the evaluation index.

After determining the fuzzy rough set of the evaluation indicators, the indiscernible evaluation indicators in the universe are approximated up and down, so that the risk evaluation indicators can be transformed into distinguishable indicator data, namely:

$$R_{up}(x) = \text{infomax}(1 - R(x, y), B(y)) \quad (4)$$

$$R_{down}(x) = \text{infomax}(1 - R(x, y), A(y)) \quad (5)$$

In formulas (4) and (5), $R_{up}(x)$ represents the approximation result on the risk assessment index, $R_{down}(x)$ represents the approximation result under the risk assessment index, R represents the fuzzy coefficient, $A(y)$ represents the feature factor in a finite theory field, and $B(y)$ represents the feature set in a finite set.

After the risk assessment indicators are resolved, in order to enable the indicators to reflect more information during the assessment, it is necessary to further determine the importance of the risk assessment indicators in the pre-processing. In this paper, F-score is used for calculation. This value is used to judge the difference between positive and negative samples of each dimension feature in the risk assessment indicators. The larger the value, the higher the importance of the risk assessment indicators. The calculation formula is:

$$E(i) = \frac{(d_i^{(+)} - d_i)^2 + (d_i^{(-)} - d_i)^2}{\frac{1}{f_i - 1} \sum_{i=1}^n (d_i^{(+)} - d_i) + \frac{1}{f_i - 1} \sum_{i=1}^n (d_i^{(-)} - d_i)^2} \quad (6)$$

In formula (6), $d_i^{(+)}$, d_i and $d_i^{(-)}$ represent the mean, positive sample value and negative sample value of the i^{th} evaluation index feature sample, respectively. f_i represents the sample feature value of the feature of the i^{th} evaluation index, and n represents the number of evaluation indicators.

In determining the key degree of human resource outsourcing risk assessment indicators, the information dimension contained in different indicators is also the basis for measuring the key degree of the indicators. Therefore, by calculating the information gain of risk indicators, can determine the amount of information in different risk indicators and provide more effective indicators for subsequent evaluation. The information gain of different risk assessment indicators is calculated as follows:

$$S(X) = -\sum_{i=1}^n V_i \log_2 V_i \quad (7)$$

In formula (7), $S(X)$ represents the information gain value of different risk indicators, and V_i represents the proportion of information in the i^{th} evaluation index.

In the pre-processing of human resource outsourcing risk indicators, the indiscernibility of the evaluation indicators is determined by using the rough set theory, the importance of the risk indicators is calculated by using F-score to calculate the risk evaluation indicators, and the information gain of the risk indicators is calculated to complete the pre-processing of human resource outsourcing risk indicators.

3 Risk evaluation of human resource outsourcing based on risk matrix method

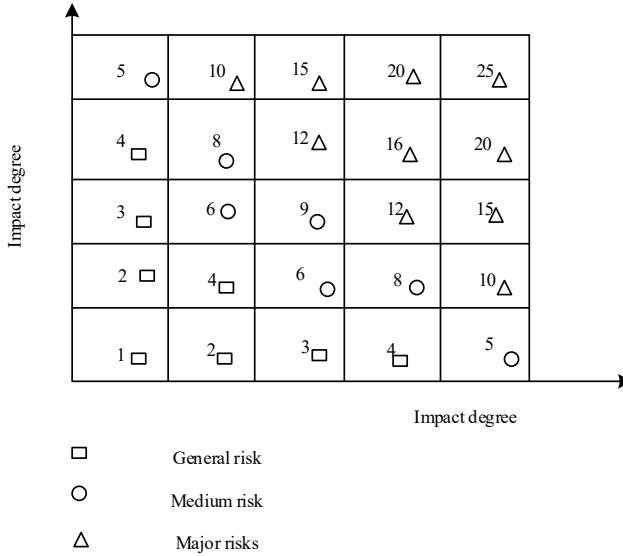
According to the above determined enterprise human resources outsourcing risk assessment indicators, in order to reduce enterprise risk, this paper introduces the risk matrix method to achieve effective evaluation of outsourcing risk. Risk matrix method is a method to identify the importance of project risk, evaluate the feasibility of the project, excavate potential risks, and conduct quantitative and qualitative analysis. This method can directly determine the relationship between risk factors and directly find the factors with high risks. Risk matrix method is a method to identify the importance of project risks, evaluate the feasibility of the project, dig out potential risks, and conduct quantitative and qualitative analysis. The risk matrix method can quickly identify the project risk factors and determine the nature of the project according to the degree of risk impact. It often uses a two-dimensional table to carry out semi qualitative analysis of risk, which has the advantage of simple and fast operation, so it is widely used. This method presents a two-dimensional state in the evaluation. It ranks the risk and relevance of the project related factors to a certain extent, and evaluates according to the size of the risk. The basic principle of this method is to effectively allocate the risk size, convert it into inconsistent factors, divide it into different areas, and display different properties of different areas in different colours. If the display colours are consistent, it means that the risk degree between the two factors is consistent.

The risk matrix (Xuan et al., 2022; Yorks et al., 2022) identifies the risk factors of the evaluation indicators in the risk assessment of human resource outsourcing of the entire enterprise. During the construction of the evaluation model, it is constructed through the probability of the actual risk occurrence and the degree of impact of the consequences of

the risk occurrence. At the same time, these values are quantified to a certain extent, and the risk matrix is divided according to the risk level for the final effective assessment. The specific steps of enterprise HR outsourcing risk assessment are as follows:

Step 1 Identify outsourcing risks. First, build a risk matrix coordinate chart, and take the risk impact results as the horizontal axis and the vertical axis as the probability of risk occurrence. According to the demand of risk control, the numerical range of qualitative and quantitative outsourcing risks is used to identify the human resource outsourcing risks of enterprises, as shown in Figure 4.

Figure 4 Schematic diagram of human resources outsourcing risk identification matrix



According to the constructed risk identification matrix, calculate the compatibility matrix of different outsourcing risk indicators to ensure the consistency of identified risks, namely:

$$e_{ij}^m = E[e_{ij}^m]^{-1} \tag{8}$$

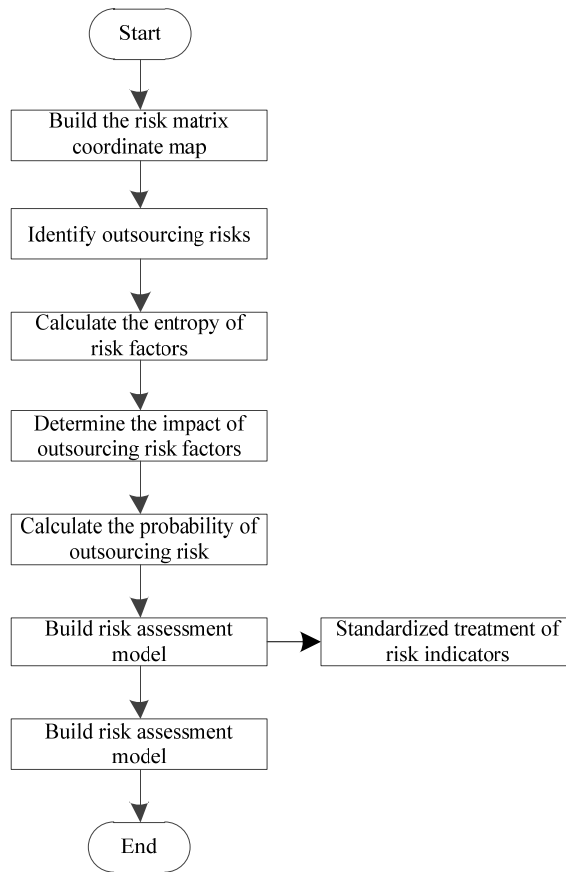
In formula (8), E represents the judgment matrix, and e_{ij}^m represents a constant indicator of risk identification.

Step 2 Determine the importance of HR outsourcing risks. According to the risk factors identified in the risk matrix, it is necessary to determine the importance of these influencing factors. This paper determines the importance of risk factors by calculating their entropy value, namely:

$$Z = k \ln \delta \tag{9}$$

In formula (9), Z represents the entropy of the outsourcing risk factor, k represents the proportional coefficient, and $\ln \delta$ represents the number of risk factor molecules.

Figure 5 Flowchart of enterprise HR outsourcing risk assessment



Step 3 Determine the impact of human resource outsourcing risk factors. After determining the importance of risk factors, it is necessary to determine the impact degree of these factors in the form of a binary system, namely:

$$u = -k \sum_{i=1}^n y_i \ln y_i \tag{10}$$

In formula (10), u represents the degree of HR outsourcing risk factors, y_i represents the unit entropy value, and k represents the risk type.

Step 4 Determine the probability of human resource outsourcing risk. Based on the results of the probability impact assessment of risk occurrence, this paper calculates the probability of outsourcing risk occurrence by using the conditional random field joint probability formula, namely:

$$p(x) = \frac{1}{z(x)} \exp\left(\sum_{x=1} u\gamma_i\right) / Z \tag{11}$$

In formula (11), $z(x)$ represents the feature function, γ_i represents the feature weight result, and $p(x)$ represents the probability result of risk occurrence.

Step 5 Comprehensively evaluate the results of human resource outsourcing risks of the enterprise. In this step, a risk assessment model is built based on the risk occurrence probability determined above. First, standardise the risk indicators, namely:

$$v_{ij} = \begin{cases} v_{ij} / v_{jMAX} \\ v_{jMIN} / v_{ij} \end{cases} \quad (12)$$

In formula (12), v_{ij} represents risk indicator standardisation results, v_{jMAX} represents maximum data, and v_{jMIN} represents minimum data.

According to the standardised risk indicators, a risk assessment model is built with the help of the risk matrix method, namely:

$$Q_{ij} = \frac{v_{ij}}{\sum_{i=1} v_{ij}} p(x)/u \quad (13)$$

In formula (13), Q_{ij} represents the enterprise HR outsourcing risk assessment results.

Figure 5 is the flow chart of enterprise human resource outsourcing risk assessment.

In the risk assessment of human resource outsourcing, the risk matrix coordinate chart is constructed to identify the outsourcing risk factors; calculate the entropy value of the risk factors to determine the importance, determine the influence degree of the factors in the form of a binary system, and calculate the probability of outsourcing risk with the conditional random field joint probability formula. On this basis, build a risk assessment model with the risk matrix method to complete the risk assessment.

4 Experimental analysis

4.1 Experiment scheme design

In this experiment, a small and medium-sized innovative enterprise in a certain place is taken as the research object, and the human resource management department of the enterprise is selected as the key object of the experiment. Conduct outsourcing bidding for the human resources of the enterprise, select ten bidding companies, and analyse the risk degree of outsourcing the human resources of the company to ten bidding companies. Specific experimental parameters are shown in Table 1.

According to the above experimental parameters, the methods in this paper, Zhang et al. (2021) and Zhang and Wang (2020) are selected for comparative analysis, mainly comparing the error, risk index correlation coefficient and evaluation time of the three methods for outsourcing risk evaluation of the ten bidding companies, to determine the overall effectiveness of the three methods. In order to ensure the fairness of the experiment, the experimental analysis is carried out in the same experimental environment, and the error controllability of the results is consistent.

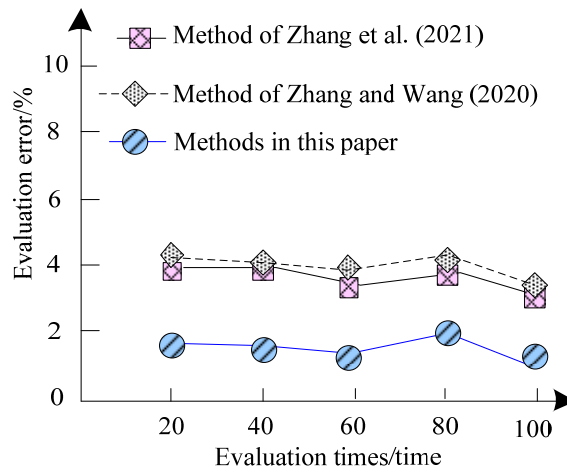
4.2 Analysis of experimental results

The experiment first analysed the error of this method, Zhang et al. (2021) method and Zhang and Wang (2020) method in outsourcing risk assessment of ten sample bidding companies, and the results are shown in Figure 6.

Table 1 Specific parameters of the experiment

Parameter	Value
Company number/person	200
HR department number/person	30
Tendering company/home	10
Risk factor index/category	4
Assessment score/score of the bidding company	>85
Degree of influence of risk factors/%	60–70
The number of assessments/times	100
The error interval was assessed	[0–1]

Figure 6 Error results of outsourcing risk assessment (see online version for colours)

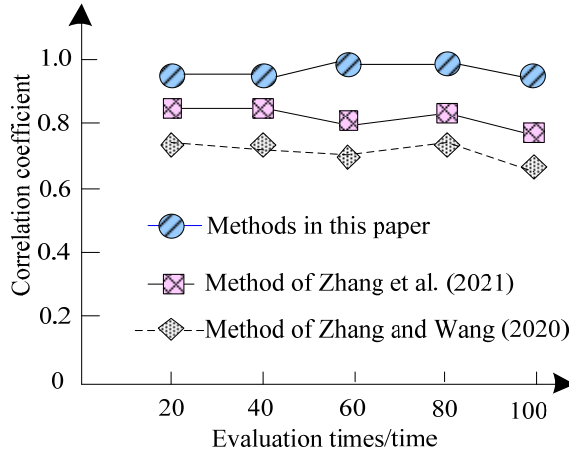


It can be seen from the analysis of the results in Figure 6 that, with the increase of the evaluation times, the error of the outsourcing risk evaluation of the sample ten bidding companies by the methods of this paper, Zhang et al. (2021) and Zhang and Wang (2020) fluctuates to some extent, but the fluctuation is not obvious. It can be seen from the level of the curve that the error curve of this method is at the lowest point, and is always lower than 2%. The results of the other two methods are always higher than this method, which shows that the evaluation effect of this method is better.

Taking the correlation coefficient of risk indicators as an experimental indicator, the value range of the coefficient is [0, 1]. The larger the value of the coefficient, the more important the criticality of the risk indicators in the assessment. The results are shown in Figure 7.

By analysing the results in Figure 7, it can be seen that there are some differences in the correlation coefficients of risk indicators obtained by the methods of this paper, Zhang et al. (2021) and Zhang and Wang (2020). Among them, the method in this paper has the largest correlation coefficient, which is close to 1, while the correlation coefficient of the other two methods is lower than the method in this paper. It can be seen that the index evaluated in this paper is more critical.

Figure 7 Analysis of risk indicator correlation coefficient results (see online version for colours)



At the end of the experiment, the time consuming of this method, Zhang et al. (2021) method and Zhang and Wang (2020) method for outsourcing risk assessment of 10 sample bidding companies is analysed, and the results are shown in Table 2.

Table 2 Time consuming results of outsourcing risk assessment by different methods (s)

<i>The number of assessments/times</i>	<i>The method of this paper</i>	<i>Zhang et al. (2021) method</i>	<i>Zhang and Wang (2020) method</i>
20	5.2	5.9	5.7
40	5.6	6.2	6.2
60	5.6	6.8	6.8
80	5.8	7.1	7.5
100	5.7	7.5	7.9

By analysing the experimental data in Table 2, it can be seen that under the same experimental environment, the time consuming for outsourcing risk assessment of ten bidding companies using the methods in this paper, Zhang et al. (2021) and Zhang and Wang (2020) is different. Among them, the lowest evaluation time of this method is 5.2 s, and the lowest evaluation time of Zhang et al. (2021) method and Zhang and Wang (2020) method is 5.9 s and 5.7 s respectively. Compared with this method, it takes less time and has higher evaluation efficiency. This is because the method in this paper uses the rough set theory to determine the indiscernibility of the evaluation indicators. The rough set theory does not need any preparatory or relevant data information, which can effectively reduce the time consumption of risk assessment and improve the efficiency of risk assessment.

5 Conclusions

There are some risks in enterprise human resource outsourcing. Therefore, this paper designs a risk assessment method of enterprise human resource outsourcing based on risk matrix method. The innovation of this method is as follows:

- 1 With the help of rough set theory, the indiscernibility of evaluation indicators is determined. F-score is used to calculate the importance of risk indicators, calculate the information gain of risk indicators, build a risk matrix coordinate map, identify outsourcing risk factors, and improve the accuracy of risk assessment.
- 2 Calculate the entropy value of risk factors to determine the importance, and use the conditional random field joint probability formula to calculate the probability of outsourcing risk occurrence to build a risk assessment model and complete the risk assessment.
- 3 The experimental results show that the evaluation error of the proposed method is less than 2%, and the correlation coefficient of the evaluation risk index is close to 1, indicating that the evaluation effect is good and the application value is higher.

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