The Third Party Logistics Supplier Selection and Evaluation

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Abstract—Corporation's own-running logistics are often inefficient, so more and more corporations would like to choose outsource logistics, that is, corporations use the third-party logistics suppliers to provide logistics services. The third-party logistics can simplify the distribution sectors, transport reasonably, use and allocate rationally the existing resources, and avoid the problems of funds used, low transportation efficiency, complicated distribution sectors and urban pollution increase brought by the own-running logistics. The third-party logistics can meet the requirements of low-carbon and environmental protection. When considering the logistics outsourcing, the selection of the third party logistics providers is the most important part, only selecting the appropriate logistics providers, enterprises can improve their competitiveness. To select the appropriate logistics providers, an effective evaluation method is essential. This paper identified a reasonable evaluation index system, and based on it, using the combination method of AHP and entropy to evaluate the third-party logistics providers comprehensively. This paper used analytic hierarchy process to determine the weight of each indicator firstly, then used the information entropy to calculate the options of the third-party logistics providers, and calculated the final score using the integrated calculating method finally, so as to determine the final option. The comprehensive evaluation method can evaluate the logistics providers by the combination of subjective and objective, and ensure enterprises to choose the third-party logistics provider more scientific and reasonable. Finally, this paper took the third party logistics provider selection of an agricultural products processing enterprise as an example in Heilongjiang Province, to prove the method practical.

Index Terms—analytic hierarchy process; information entropy, the third-party logistics providers, evaluation index system

I. INTRODUCTION

With the development of the theory and practice of logistics management, logistics outsourcing has been one of the important ways for many companies, which can reduce logistics cost and improve the logistics service level. The third party logistics can bring many benefits to its users; it is conducive to industry concentration, investment reduction in fixed assets, costs reduction on logistics, the enhancement of corporate image, and so on. However, to make full advantage of third-party logistics play out, we must select the appropriate third-party logistics providers, if you choose incorrectly, the enterprise's logistics outsourcing strategy not only will fail to achieve, but will pose some risks for enterprises. For example, the reduction of the controlling power, the failure management of customer relationship, the joint risk of management and so on. Therefore, selecting the most suitable third party logistics supplier is of great importance for the enterprise’s development. And how to select the best partner has been a hot issue concerned by business community and the academia.

The third-party logistics is referred to the external providers providing all or part logistics service for corporations. The services provided by the third-party logistics include mainly transportation, warehouse management, and distribution, and so on [1]. The third-party logistics is neither the supply side, nor the demand side, but a business model provided by the supply-side and demand-side logistics enterprises. The third-party logistics provides not real products, but services.

In order to select the most suitable third party logistics providers, choosing the evaluation methods is essential. We should adopt a reasonable and effective evaluation method to evaluate comprehensively, so as to assure the scientific of results.

II. THE THIRD-PARTY LOGISTICS SUPPLIER SELECTION METHODS REVIEW

In the process choosing the third-party logistics providers, the methods are mainly two types of qualitative and quantitative. Supplier selection methods are mainly qualitative experience to determine the method, public tender law, selection method consultation, benchmarking method, etc. Currently, domestic and international supplier selection method for the study focused on quantitative models. From the collection of literature, the most commonly used logistic model for supplier selection and evaluation are as follows:
A.  AHP.


B.  Data Envelopment Analysis (DEA).

Yao Chen, Joe Zhu [6] [2003] used both parties two stages game model to simplify DEA model, to establish an efficiency interval, and to select suppliers. Chuan Xu Wang [7] [2004] used the SE-DEA method; YongRui Duan, Tian Peng, WeiPing Zhang [8] [2004], Ao Chen [9] [2007], also used the DEA method to select and evaluate the third party logistics provider.

C.  Fuzzy Comprehensive Evaluation Method.

CebeciU[10] [2001], LiJiang Zhao [11] [2003], KaiYuan Liu [12] [2004], ChengWu Fang, XunPing Lei [13] [2005], MinTun Li [14] [2006], YiXin Shi, DanSong zhang [15] [2006], a large number of studies used fuzzy comprehensive evaluation method to select and evaluate the third party logistics supplier.

D.  Statistical Analysis Method.

Rong Chen [16] [2007] adopted the principal component analysis method. ChunXia Chen, ZhiBin Yu [2007] adopted the fuzzy clustering method to select the third party logistics supplier.

E.  Other Models Are Also Widely used in the Selection of Logistics Supplier

SeongKo Chang [17] [2000] proposed the usage of the tabu search algorithm on the selection of logistics supplier; Ghodsypour S H, Brien C O [18] [2001] researched the selection of logistics supplier from the perspective of overall costs; Qureshi M N, Dinesh Kumar, Pradeep Kumar [19] and Wadhwa S., Madaan J [2003] adopted multiple strategic decision method to select the logistics supplier respectively; Manoj Kumar [20] [2004] established constraints from three ways - maximum satisfaction, the least net cost and minimum time delay, and used fuzzy optimization theory for supplier selection; Weiqing Zhong [21] [2003] adopted the neural network analysis method; Xuejun Cui and Ji cheng Zhan [22] adopted the improved Gray Correlation Analysis; zhiJiao Lei [23] [2004] used fuzzy clustering analysis method; Sizhi Li and Yanhong Li [24] [2005] adopted the set pair analysis method; Dong Wang, Bing Tian and Xiaolong Tang [25] [2007] adopted the TOPISIS method; Juning Su and Juhong Su [26] [2006] adopted multilevel grey evaluation method for logistics partner selection.

These evaluation methods evaluated the third logistics more scientific and objective from different angles, but some of them ignored the objective factors, and some of them ignored the presence of uncertainty and opposed factors in reality the operation [27]. So these methods may result in improper choice of logistics providers, and affect the benefits of enterprises. This paper built the model of AHP/information entropy, using the combined method of AHP and information entropy to evaluate and select the third-party logistics providers, and the model can help corporations to choose the third-party logistics providers scientifically and rationally.

III. Evaluation Index System

A. The Selection Steps of the Third-party Logistics Supplier

The choice of the third-party logistics providers can be categorized into the following steps[28]: Needs analysis, establish the goals of supplier selection, draw up supplier evaluation criteria, establish the evaluation team, coarse screening to suppliers, comprehensive evaluation to suppliers, select suppliers, implement and maintain the supply chain partnerships, tracked evaluate to suppliers and feedback and improvement. Detail is shown in Figure 1.

B. The Principles of Setting Up the Index System

• Overall systematic principle: It is requested that the established index system not only can reflect the historical performance and status of the supplier enterprise, but also can reflect the cooperation ability and the future development potential of the supplier.

• Purposely principle: The index system should be able to describe the substitutive characteristics, structure and its inscapes of the target enterprise objectively, at the same time can state the relevant elements which the cooperation depends on objectively, and services for the assessment purpose, provides the basis for cooperative partners.

• Scientific practical principle: The index system should be able to reflect the actual situation of suppliers, objectively and practically. The index system should be in moderate scale. If index system is too large, has too many levels, and the index is too meticulous, it will not reflect the overall evaluation attention. And index system is too small, the index is too thick, it can't reflect the actual levels of suppliers.

• The principle of combining quality and quantity: When the target enterprise is in the evaluation, not all the index can be quantified, so it must be combined with quality and quantity.

• Extended principle: Because each industry and enterprises in one industry have their own special requirements, therefore, some special index should be added. This requires the index system and the corresponding evaluation models have expanded space.
C. Access Methods of the Indicators.

This paper used literature research, interviews and questionnaires to obtain the evaluation index of the third-party logistics providers. The methods are as follows:

- **Literature research**: Through researching some related literatures at home and abroad, such as the evaluation of the third party logistics provider selection, supplier selection and evaluation of business, and business logistics, and so on, this paper sorted out some evaluation indicators about the third-party logistics supplier.

- **Interview**: Through interviewing with the professors and experts in some university majored in logistics and supply chain, this paper got some indicators affecting companies to choose the third-party logistics supplier.

- **Questionnaire**: This paper selected 13 agricultural products processing enterprises in Heilongjiang province as the survey object, and each enterprise is paid 4 to 5 questionnaires. The main investigation subjects are those engaged in purchasing, logistics management and production operations management. This paper obtained some indicators through the questionnaire.

D. Evaluation Index System of the Third-party Logistics Supplier Selection.

Evaluate index system. This paper sorted out the third party logistics supplier evaluation index system by above-mentioned approach (Table 1).

Meanings of indicators. The evaluation index system includes 5 second-level indicators and 21 third-level indicators, and their meanings are as follows:

- **Operational capability**: Operational capability is the most basic capabilities of the logistics enterprises, and it is the base reflects of the competitive advantage of the logistics enterprises. Logistics enterprises only operate with a higher operational capability, low cost and high level of service just to achieve. Operational capacity includes mainly vehicles achieving logistics business, warehouses and logistics centers, and quality capabilities enterprises providing logistics services, and so on. Specific indicators include: transportation and distribution capacity, storage capacity, ability providing value-added services, level of information, and ability of personalize [1].

- **Service levels**: Service level is the result of a series of logistics activities in order to meet the logistics needs of customers. The nature of logistics is services, which itself only create space for utility goods and time effectiveness, and do not create the form quality effects. Specific indicators include: order processing efficiency, delivery accuracy, time shipping rate, time delivery rate, customer satisfaction, and network coverage [29].

- **Price level**: Price is one of the most important indicators of enterprises choosing the third-party logistics provider. The price level of the third-party logistics services will not only affect the operating costs of the enterprises, but also reflects from the side the logistics technology capabilities of the selected third-party logistics provider. Specific indicators include: basic service price and variable price [30].

- **Development potential**: The development potential of the third-party logistics providers mainly account of its' future development prospects, so enterprises can decide whether the long-term business cooperation or not. Long-term and stable cooperative relations can reduce costs, mutual understanding and trust, so can improve the logistics system flexibility and reliability. Specific indicators include: corporate culture, corporate reputation, management level, staff quality and technical innovation capability [31].

- **Green level**: The purpose of green logistics is to reduce environmental pollution, and reduce resource consumption. It emphasizes the global and long-term interests and strengthens the full range of environmental and resource concerns while obtaining economic benefits. Specific indicators include: pollutant emissions, energy consumption, reuse of resources [32].
TABLE I. EVALUATION INDEX SYSTEM

<table>
<thead>
<tr>
<th>First-level indicators</th>
<th>Second-level indicators</th>
<th>Third-level indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Capability (a1)</td>
<td>Transport and distribution capabilities (a11)</td>
<td>Ability of personalization (a12)</td>
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<tr>
<td></td>
<td>Storage Capacity (a12)</td>
<td>Ability of providing value-added services (a13)</td>
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<td></td>
<td>Level of information (a13)</td>
<td>Level of information (a14)</td>
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<tr>
<td>Service levels (a2)</td>
<td>Order processing efficiency (a21)</td>
<td>Delivery accuracy (a22)</td>
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<tr>
<td></td>
<td>Time shipping rate (a22)</td>
<td>Time delivery rate (a23)</td>
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<td></td>
<td>Customer satisfaction (a23)</td>
<td>Network coverage (a24)</td>
</tr>
<tr>
<td>Price level (a3)</td>
<td>Prices of basic services (a31)</td>
<td>Variable price (a32)</td>
</tr>
<tr>
<td>Development potential (a4)</td>
<td>Corporate culture (a41)</td>
<td>Corporate reputation (a42)</td>
</tr>
<tr>
<td></td>
<td>Management level (a42)</td>
<td>Staff quality (a43)</td>
</tr>
<tr>
<td></td>
<td>Technological innovation capability (a43)</td>
<td>Corporate reputation (a44)</td>
</tr>
<tr>
<td>Green level (a5)</td>
<td>Pollutant emissions (a51)</td>
<td>Energy consumption (a52)</td>
</tr>
<tr>
<td></td>
<td>Reuse of resources (a53)</td>
<td></td>
</tr>
</tbody>
</table>

IV. INTRODUCTION OF THE EVALUATION METHODS

A. Analytic Hierarchy Process

AHP is an abbreviation of the Analytic Hierarchy Process, and it is a systems analysis method originated by T.L. Saaty who is a famous United States operational researcher at the beginning of the seventies. Now it is widely used in areas such as strategic decision, forecasting and assessment, and so on.

According to the problem’s nature and the overall goal, AHP breaks complex problems into different factors in ordered delivery structure which has been grouped by dominating relationship, and then people can determine the relative importance of each factor by the method of comparison of every two factors. Finally, people should consider the results of judgment comparatively to determine the total order of the various factors relative importance. One of the most critical issues is how to get the weight of evaluation indexes and the weight of each program under each evaluation index.

The general process of AHP includes several steps, such as the creation of the analytic structure model, the structure of consistency judgment matrix, the single sorting of hierarchy factors and hierarchical comprehensive ranking.

B. Information Entropy

The concept of entropy is from the thermodynamic, and it describes an irreversible phenomenon in the motion process. Using entropy to represent the uncertainty of things in information theory, and the greater the uncertainty, the greater the entropy, and the greater the amount of information needed. The concept of information entropy is proposed by C. E. Shannon in 1948. Information entropy is used to measure the amount of information, and the more ordered a system, the lower entropy becomes; on the contrary, the more chaotic a system, the higher the entropy. The Entropy is calculation formula is as follows [33]:

\[ H(\mathbf{X}) = -\frac{1}{\ln m} \sum_{i=1}^{m} p(x_i) \ln p(x_i) \]  

(1)

V. AHP / INFORMATION ENTROPY MODEL

AHP / information entropy model includes three steps:

A. Construction of Matrix with the AHP and calculate the weight of subjective indicators

Select the comparison scale. This paper used 1-9 scale method (T.L. Saaty). The meanings of the scale are shown in Table II.

Construct the judgment matrix. Experts assigned to the importance degree of elements according to 1-9 scale method and construct the comparison matrix. The form is as follows:

\[ \mathbf{A} = (a_{ij})_{n \times n} \]  

(2)

where \( a_{ij} > 0 \), and \( a_{ij} = 1/a_{ji} \)

Calculate the weight and the largest eigenvalue. The weights of evaluation indicators are the eigenvectors of the judgment matrix. This paper used the square root to calculate the weight, and the calculation process is as follows:

- Each row elements of judgment multiply, denoted by \( M_i \);
- Calculating the n-th root \( M_i \), denoted by \( W_i \);
- Normalize to the vector \( \mathbf{W} = (W_1, W_2, ..., W_n)^T \), as follows:

\[ W'_i = \left( \frac{W_i}{W_1 + W_2 + ... + W_n} \right)^{(i=1,2,...,n)} \]

\[ w = (W'_1, W'_2, ..., W'_n)^T \] , \( W \) is the approximate solution of the eigenvector.

Calculated the to maximum eigenvalue \( (\lambda_{max}) \) of the judgment matrix

\[ \lambda_{max} = \sum_{i=1}^{n} \left( \frac{BW_i}{nW_i} \right) \]  

(3)

Consistency test

- consistency test to the judgment matrix by consistency index (CI)

\[ CI = \frac{\lambda_{max} - n}{n - 1} \]  

(4)

- The standards of the judgment matrix are the average random indicators consistency index (RI),
and the indictor is only concerned with the matrix order. Calculate formula is as follows:

$$CR = \frac{CI}{RI}$$  \hspace{1cm} (5)$$

When CR <0.1, the paired comparison matrix has a satisfactory consistency, or its inconsistency degree is acceptable; otherwise adjust the paired comparison matrix till it reaches the consistency of satisfaction.

B. Determine the Objective Weight by Information Entropy

Shannon said: entropy method is a method of determining the weights by the judgment matrix compose of the value of evaluation indictors in objective conditions.

- Constructing a judgment matrix with m programs and n evaluation indictors.
- Index standardization. Because the dimensions of each index are different, indictors dimensionless is necessary in order to compare comfortably.

Assume $x_{ij}$ is the result of dimensionless, and the standardized formula is as follows:

$$P_{ij} = \frac{X_{ij}}{\sum_{i}^{m} X_{ij}} \hspace{1cm}(i=1,2,\cdots,m)$$

The standardized matrix: $P=\{p_{ij}\}_{m \times n}$

- According to the definition of entropy, we can determine the information entropy of the indicator $j(H_j)$:

$$H_j = -\frac{1}{\ln m} \sum_{i}^{m} p_{ij} \ln p_{ij} \hspace{1cm} (j=1,2,\cdots,n)$$  \hspace{1cm} (7)$$

- Calculate the entropy of the indicator $j (W_j^S)$:

$$W_j^S = \frac{1}{m - \sum_{i}^{m} H_i} \hspace{1cm} (8)$$

- Construct comprehensive evaluation model

The weights determined by AHP reflect the experts’ sort on the importance of various indicators. Information entropy reflects the objective existence relationships of properties values based on the supplier, combine the two methods, and consider both the subjective and objective factors, so that we can evaluate the three logistics objectively and reasonably.

Combined the subjective weights from experts and makers $W_j^S, W_j^1,..., W_j^n$ and the objective weight $W_j^S$, the final weight of indicators are:

$$W_j^* = \frac{W_j^S}{\sum_{i=1}^{n} W_j^*}, \hspace{1cm} 0 \leq W_j^* \leq 1. \sum_{i=1}^{n} W_i^* = 1$$  \hspace{1cm} (9)$$

$W_j^*$ is for the comprehensive weight, $W_j^S$ is subjective weight determined by AHP, $W_j^1$ is for the objective weight determined by the entropy weight method.

C. Indictors Dimensionless

Given the defect of various dimensionless methods, the paper uses the concept of membership function in fuzzy mathematics to do dimensionless to the maximum and minimum of the score. The conversion formula is as follows:

Fuzzy quantification for the positive indicators class and the evaluation results after treatment strictly monotone increasing.

$$R_{(x)} = \left \{ \begin{array}{ll} 1 & x_{min} \leq x_j < x_{max} \\ 0 & x_j < x_{min} \end{array} \right \} \hspace{1cm} (10)$$

Fuzzy quantification of negative indicators class, evaluation results after treatment strictly monotone decreasing.

$$R_{(x)} = \left \{ \begin{array}{ll} 1 & x_{min} < x_j < x_{max} \\ 0 & x_j \geq x_{max} \end{array} \right \} \hspace{1cm} (11)$$

D. Comprehensive Evaluation Value of indictors

The scores experts on various indicators were $R_1, R_2, ..., R_n$ after dimensionless, the values are $R_1^*, R_2^*, ..., R_n^*$ and the comprehensive weight of various indicators is $W_1^*, W_2^*, ..., W_n^*$. Then the final score of the third party suppliers:

$$T = [R_1^*, R_2^*, ..., R_n^*]$$  \hspace{1cm} (12)$$

V. USE OF THE MODEL OF AHP/ INFORMATION ENTROPY IN THIRD-PARTY LOGISTICS SUPPLIER SELECTION

EVALUATION

Because the development level of logistics technology in Heilongjiang Province is lower, the third party logistics’ development of the agricultural products is restricted. At present, the circulation of agricultural products in Heilongjiang Province is still mainly on the way of own-running logistics. In order to reduce energy consumption, and implement green logistics, agricultural products processing enterprises in Heilongjiang province decide to outsource logistics to third-party logistics providers, hoping to reduce logistics costs, reduce environmental pollution and improve the level of competitiveness.

After the primaries election, there are two logistics providers as the candidate suppliers. We use the five indicators discussed in front of contents as evaluation indictors. Evaluation steps are as follows:

A. Determination of the Subjective Weight

This paper invited two researchers majored in logistics and supply chain and four senior managers engaged in an operation and management in agricultural products processing enterprises in Heilongjiang province, distributed the judgment matrix forms to them, and they completed the forms according to the scale 1-9, and we got the judgment matrix. Finally we use the software of AHP to calculate feature vectors according to the square root of, and calculate the weights of each indictor. The results are as shown in Table III.
B. Data Collection

The evaluation group was established by the six experts determined the weight of indicators in index weights. They score to the two logistics providers according to the evaluation criteria of the evaluation indicators. The evaluation sample matrix is shown in Table IV.

<table>
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<tr>
<th>First-level indicators</th>
<th>Second-level indicators</th>
<th>Third-level indicators</th>
<th>Total weight (W)</th>
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<td>C₁ Service levels</td>
<td>c₁₂ Prices of basic</td>
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<td>c₁₃ Variable price</td>
<td>0.0300</td>
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<td>C₂ Development</td>
<td>c₂₁ Corporate Culture</td>
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<td>c₂₂ Corporate reputation</td>
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<td>c₂₃ Management level</td>
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<td>c₅₇ Technological</td>
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</tbody>
</table>

CR=0.01. Consistency test is passed.

According to the formula (10) and (11), the data processing result to table 4 is shown as Table V.

<table>
<thead>
<tr>
<th>TABLE III. SUBJETIVE WEIGHT</th>
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<tbody>
<tr>
<td>Services price(c₄)</td>
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<td>----------------</td>
</tr>
<tr>
<td>83</td>
</tr>
<tr>
<td>Variable price(c₅)</td>
</tr>
<tr>
<td>89</td>
</tr>
<tr>
<td>Corporate reputation(c₄₂)</td>
</tr>
<tr>
<td>91</td>
</tr>
<tr>
<td>Staff quality(c₄₄)</td>
</tr>
<tr>
<td>93</td>
</tr>
<tr>
<td>Technological innovation capability(c₄₆)</td>
</tr>
<tr>
<td>76</td>
</tr>
</tbody>
</table>

According to the formula (7), the information entropy values are as follows:

\[ H_i = [0.4012, 0.2871, 0.3892, 0.1407, 0.4385, 0.5015, 0.2783, 0.5160, 0.5057, 0.6214, 0.3981, 0.4576, 0.1995, 0.3588, 0.6216, 0.0981, 0.3639, 0.2855, 0.3622, 0.4387, 0.3715] \]

According to the formula (8), the entropy values are as follows:

\[ W_j = [0.0992, 0.1181, 0.1012, 0.1424, 0.0930, 0.0826, 0.1196, 0.0802, 0.0819, 0.0627, 0.0997] \]
According to formula (9), the integrated weights are as follows:

\[ W_j^* = (0.1066, 0.0647, 0.0277, 0.0180, 0.0059, 0.0348, 0.0907, 0.0304, 0.0932, 0.0845, 0.0168, 0.0852, 0.0419, 0.0125, 0.0153, 0.0153, 0.0202, 0.0113, 0.1145, 0.0411, 0.0714) \]

Finally, According to formula (12) and Table 4, we can draw the final evaluation score of supplier I and supplier II:

\[ T_I = 0.6059, \quad T_II = 0.4574 \]

According to the final score, we can determine the optimal supplier of a third-party logistics enterprise provider is supplier I.

This paper built the model of AHP / information entropy for the third-party logistics provider selection. The model combined the subjective analysis and objective analysis. AHP reduced the subjectivity of the decision-making problems to some extent, making the evaluation and selection process can be quantified, and the information entropy method avoided impact of our subjective judgments to the supplier evaluation. Calculation of the model is simple, we can calculate through software and excel spreadsheet, the results are scientific and simple, and more effectively solve the uncertainty questions of the third party logistics supplier evaluation and selection. The example shows that the model of AHP / information entropy has a certain value of promotion and application, and it is an effective way solving the third-party logistics providers choose and evaluation.

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Issues commitment or involved in recent years:
Virtual Enterprise Information System Research (Harbin, Heilongjiang Province, 2006);
Matter-element analysis based on risk assessment model of virtual enterprise (Harbin, Heilongjiang Province, 2007);
Project-oriented organization model and management of virtual enterprise (Harbin, Heilongjiang Province, Xiu Guoyi, 2007);
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