Enterprise Emergency Logistics Capability Evaluation Research Based on Rough Set and Unascertained Measurement Model

Xiangyang Ren, Xue Wen, Shu Wang and Xiaotong Niu

Abstract—**This paper analyzes the indicators that influence enterprise emergency logistics capability under the unconventional emergencies from six aspects. First, the paper reduces the redundant indicators by using rough set theory. Then it uses the unascertained measurement model to get a comprehensive evaluation. Finally, the paper puts the specific example into the empirical analysis, to demonstrate the effectiveness and feasibility of this method.**

Index Terms—**emergency logistics capability, rough set, reduction, unascertained measurement, information entropy**

I. Introduction

Unconventional emergencies are characterized by obvious complexity and potential secondary derivative hazard and serious destruction, whose omen is not sufficient, the conventional management mode is difficult to effectively respond to the emergencies. It is divided into four categories: natural disasters, accidents, public health and social security incidents [1]. The unconventional emergencies have characteristics of fulminating, particularity, the complexity of the environment, population diffusion and the uncertainty of evolution. Emergency logistics is defined as a response to this incident, and it is a special logistics activity which provides urgent guarantee for the needs of materials, personnel and funds. Emergency logistics capability is a specific emergency logistics system, which is the concentrated expression of the response time, response speed, logistics cost, punctuality of order completion and reliability of order delivery from the whole process that includes emergency needs analysis, emergency demand confirmation, emergency procurement, sorting, transport and deliver to emergency client. General logistics emphasizes on efficiency and benefit, emergency logistics realizes the logistics benefit by the logistics efficiency in most cases. Enterprise emergency logistics capability is particularly important, for it relates the victims' lives and property safety. Therefore establishing a scientific and reasonable evaluation index system of enterprise emergency logistics capability is imperative.

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X. Y. Ren was with China University of Mining and Technology, Beijing, P.R.China. He is now with School of Economics and Management, Hebei University of Engineering, Han Dan, 056038, P.R.China, (phone:+86 0310 8579373; e-mail: boyrenxy@126.com).

X. Wen is now with School of Economics and Management, Hebei University of Engineering, Han Dan, 056038, P.R.China, (e-mail: tearsmissing@126.com).

S. Wang is now with School of Economics and Management, Hebei University of Engineering, Han Dan, 056038, P.R.China, (e-mail: wssllh@126.com).

X. T. Niu is now with School of Economics and Management, Hebei University of Engineering, Han Dan, 056038, P.R.China, (e-mail: nxt8661@163.com).

II. Research Status at Home and Abroad

A. The Related Research Status on Emergency Capability Evaluation

1) The Abroad Related Research on Emergency Capability Evaluation

In terms of emergency capability assessment practices, the United States is the earliest and most mature state in carrying out emergency research in the world. Because the related evaluation indexes are comprehensive, many countries and regions began to imitate. In addition to the United States, Japan in the special geographical location, Australia and Canada for their conditions in the emergency have also done a lot of work. Manoj etc. evaluated emergency capability from three aspects, including mitigation stage: community disaster preparedness level, the effectiveness of the warning system; response phase: assessment of the impact of disasters; recovery phase: public evaluation and individual evaluation [2]. Wilson etc. evaluated Australian current practices on natural disaster management from the following aspects: the policy measures relating disaster, disaster preparedness measures, mitigation measures, emergency response, post-disaster assessment, disaster risk assessment, restoration measures, and made clear advantages and disadvantages and put forward the reform proposal [3].

2) The Domestic Related Research on Emergency Capability Evaluation

The research and implementation on emergency capability assessment are just carried out in the domestic, our country began to pay attention to the emergency capability research after the SARS in 2003, showing serious short board phenomenon in many details of the organization construction. Deng etc. established a set of indexes including the management mechanism, the emergency center, professional team, full-time staff and volunteers, risk analysis, monitoring and early warning, command and coordination, disaster prevention and mitigation to evaluate the city emergency capability [4]. Tian etc. researched emergency capability from the aspects of pre-disaster warning, disaster emergency response ability, post-disaster recovery ability [5].

B. The Related Research Status on Emergency Logistics Evaluation

1) The Abroad Related Research on Emergency Capability Evaluation

In the aspect of concept, Ozdamar etc. defined emergency logistics as a process which plan effectively, manage and control the disaster relief materials, information and services, to ensure its smooth, arriving to demand in time, to meet urgent needs of the victim under the emergency situation [6]. Reddy etc. pointed out that emergency logistics is a logistics activity as the result of sudden factors, including emergency logistics demand generated by the sudden factors and emergency logistics supply activities meeting the logistics requirements [7].

2) The Domestic Related Research on Emergency Logistics Concept and Capability Evaluation

In terms of the concept of emergency logistics, Ou etc. put forward that the logistics is a special logistics activities and aims at providing emergency supplies needed by unexpected natural disasters, public health emergencies, in order to maximize the effectiveness and minimize disaster losses [8]. In the evaluation, Zhou etc. built emergency logistics support capability evaluation system from the command and dispatch, management implementation, information management three aspects [9]. Xu etc. assessed emergency logistics real-time response ability from the inventory activity, transport activity, packaging activity, handling activity and logistics information activity in five aspects [10]. Lin etc. used the ANP analytic network process to determine the index weight of each level, and applied multilevel grey evaluation method for emergency logistics capability evaluation [11]. Nie constructed the emergency logistics center ability evaluation index system under unconventional emergencies with fuzzy clustering analysis method [12]. Yao etc. set up the model of multi-level gray comprehensive evaluation based on fuzzy theory using the membership degree and grey degree theory of the grey fuzzy mathematics [13].

From above scholars' studies we can see the present research on emergency logistics capability is still not perfect and mainly focuses on natural disasters and sudden public incidents, scholars carried out research aiming at government, city emergency capability or special industries, and less involved in service firms such as logistics enterprises. In the aspect of the selection of evaluation methods, they mostly used theoretical methods, lacking practical operability, so it is difficult to promote and apply in nationwide.

III. Principle of Index Selection and the Initial Index System

So as to make the selected indexes reflect comprehensively and systematically the overall situation of enterprise emergency logistics capability, we need to follow the principles: systematic, hierarchy, scientific, practicability and qualitative combined with quantitative. By the investigation and analysis on the Han Dan logistics enterprises we gain the initial emergency logistics capability evaluation index system [14]. The initial index system is extensive and summative, and it totally includes 6 first grade indicators and 31 secondary grade indicators. As the following Table I.

TABLE I
ENTERPRISE EMERGENCY LOGISTICS CAPABILITY EVALUATION INITIAL INDEX SYSTEM

Object Layer	First Grade Indicators	The Secondary Indicators	Nature of Indicators
Enterprise Emergency Logistics Capability Evaluation Index System	Information Processing Capacity I_1	Real-time Information Monitoring Ability I_{11}	Qualitative & Positive
		Information Acquisition and Analysis Ability I_{12}	Qualitative & Positive
		Information Feedback and Share Ability I_{13}	Qualitative & Positive
		Completeness of the Information System I_{14}	Qualitative & Positive
		Security of the Information System I_{15}	Qualitative & Positive
		State of the Vehicle Cargo Tracking I_{16}	Qualitative & Positive
	Organization and Management Ability I_2	Establishment of the Emergency Plan I_{21}	Qualitative & Positive
		Judging and Command Ability I_{22}	Qualitative & Positive
		Internal and External Coordination Ability I_{23}	Qualitative & Positive
		Expert Decision-making Ability I_{24}	Qualitative & Positive
		Scientificness of the Personnel Responsibility I_{25}	Qualitative & Positive
	Support and Safeguard Ability I_3	Support of the Advanced Technical I_{31}	Quantitative & Positive
		Amount of the Emergency Equipment I_{32}	Quantitative & Positive
		Number of the Professionals Team I_{33}	Qualitative & Positive
		Communications Security I_{34}	Qualitative & Positive
		Road Conditions I_{35}	Quantitative & Positive
	Emergency Rescue Ability I_4	Material Raising and Purchasing Ability I_{41}	Qualitative & Positive
		Material Dispatching Ability I_{42}	Qualitative & Positive
		Material Distribution Ability I_{43}	Qualitative & Positive
		Material Transport Ability I_{44}	Qualitative & Positive
		Transportation Equipment Utilization Rate Effectively I_{45}	Quantitative & Positive
		Route Optimization Ability I_{46}	Qualitative & Positive
	Service Quality I_5	Fast Response Time I_{51}	Quantitative & Positive
		Logistics Transport Speed I_{52}	Quantitative & Positive
		Timeliness of the Materials Reach I_{53}	Quantitative & Positive
		Serviceability Rate of the Materials Delivery I_{54}	Quantitative & Positive
		Completion Rate of the Materials Delivery I_{55}	Quantitative & Positive
	Logistics Cost I_6	Materials Cost I_{61}	Quantitative & Negative
		Inventory CostI_{62}	Quantitative & Negative
		Transportation Cost I_{63}	Quantitative & Negative
		Social Cost I_{64}	Quantitative & Negative

IV. Rough Set Theory and Unascertained Measurement Model

A. Rough Set Theory

Rough set is put forward by Poland mathematician Z. Pawlak in 1982, which is a mathematical method used to deal with uncertain, incomplete and inconsistent data [15].

Supposing that $S=(U,A,V,f)$ is a information system. Among it U is the domain, $U=\{x_1,x_2,...,x_n\}$, it represents non-null finite sets of objects; A is the set of the attributes, $A=C\bigcup D$, it contains condition attributes and decision attributes; V is the value domain of the attributes; $f:U\times A\to V$ is a information function and it appoints every object's attribute value.

Definition 4.1.1. $K=(U,R)$ is a knowledge base, $X\subseteq U$. We define the $R_{\_}(X)=\{x\,|\,[x]_R\subseteq X,\forall x\subseteq U\}$ as the lower approximation of the rough set, also we call $R_{\_}(X)$ is R positive domain of X, expressing as $POS_R(X)$; and we define the $R^{-}(X)=\{x\,|\,[x]_R\bigcap X,\forall x\subseteq U\}$ as the upper approximation of the rough set. Positive domain $POS_R(X)$ is consist of elements completely belonging to X among U, $R^{-}(X)$ is made up of elements likely belonging to X among U, they are both a certain set.

Definition 4.1.2. $BN_R(X)=R^{-}(X)-R_{\_}(X)$ is defined as R boundary domain of X, and $NEG_R(X)=U-R_{\_}(X)$ is negative domain of X, the negative domain is consist of elements belonging to or not X.

Definition 4.1.3. Supposing that $S=(U,R)$ is an information system, R is equivalence relation family of U, $r\in R$, if $U\,|\,IND(R)=U\,|\,IND(R-r)$ (or simply described as $IND(R)=IND(R-r)$), the paper thinks that r can be reduced, or it can not be reduced.

Definition 4.1.4. Supposing that $S=(U,R)$ is an information system, if subfamily $P\subseteq U$ meets the condition $IND(P)=IND(R)$, and P is independent, we define P as a reduction of R.

Definition 4.1.5. Supposing that $S=(U,R)$ is an information system, the attributes which cannot be reduced of R are called core attributes.

Simplifying steps of decision tables:

① Condition attributes reduction, that is, to remove certain columns from the decision table;

②Removing duplicate rows;

③Removing redundancy value of attributes.

Simplifying the decision table is to simplify the condition attributes from decision table, though reducing we can get the key indicator elements influencing enterprise emergency logistics ability.

B. Unascertained Measurement Model

Since academician Guangyuan Wang put forward unascertained concept in 1990, the unascertained theory had been applied for some fields extensively and successfully.

Supposing that the universe of discourse is $X=\{x_1,x_2,...,x_n\}$, every appraisal x_i has m item indexes, $I=\{i_1,i_2,...i_m\}$. It used x_{ij} to denote observed value of object x_i under index I_j. It is supposed $C=\{c_1,c_2,...c_k\}$ as appraisal space, where, c_k （$1\le k\le K$） is the k appraisal rank.

1) Single Index Unascertained Measurement

When observed value x_{ij} of object about index I_j is different, the degree which this index makes x_i lie on each appraisal rank is also different. It is supposed that the degree which x_{ij} makes x_i lie on the k appraisal rank is $u_{ijk}=u(x_{ij}\in c_k)$. Then u_{ijk} is a measurement result to degree, and as a measurement it must content usual three kinds' measurement rule: "nonnegative and bounded nature, additive nature, and normalization", so the single index measurement appraisal matrix of object x_i:

$$u_i=(u_{ijk})_{m\times K}=\begin{bmatrix} u_{i11} & u_{i12} & \cdots & u_{i1K} \\ u_{i21} & u_{i22} & \cdots & u_{i2K} \\ \vdots & \vdots & & \vdots \\ u_{im1} & u_{im2} & \cdots & u_{imK} \end{bmatrix} \tag{1}$$

2) The Information Entropy to Determine the Index Weight

Entropy value method is a kind of objective method. Through the size of the amount of information contained in various index to determine the index weight, and avoiding subjective randomness. It is supposed that information entropy which is ascertained by measurement u_{ijk} is:

$$H(j)=-\sum_{k=1}^{K}u_{ijk}\cdot\log u_{ijk} \tag{2}$$

Order

$$V_j^i=1-\frac{1}{\log K}H(j)=1+\frac{1}{\log K}\sum_{k=1}^{K}u_{ijk}\cdot\log u_{ijk} \tag{3}$$

w_{ij} shows the classification weight of value I_j on object x_i.

Order

$$W_j^i=\frac{V_j^i}{\sum_{j=1}^{m}V_j^i}\qquad\left(0\le W_j^i\le 1,\sum_{j=1}^{m}V_j^i=1\right) \tag{4}$$

From the character of information entropy, we can know:

a) If and only if $u_{ij1}=u_{ij2}=\cdots=u_{ijk}=\dfrac{1}{k}$, v_{ij} is the minimum 0.

b) If and only if existing one $u_{ijk_0}=1$, and the others are 0, v_{ij} is the maximum 1.

c) u_{ijk} is more centralized, then the v_{ij} is more near to 1. On the contrary, u_{ijk} is more dispersed, v_{ij} is more near to 0.

From the above three characters, we can see w_{ij} is bigger, I_j is more important to identification sample classification.

So
$$W^i=(w_1^i,w_2^i,\cdots,w_m^i)^T \tag{5}$$

As the weight vector of the attribute set I.

3) Synthetically Appraisal System

We can calculate the unascertained measure recognition vector of object x_i on m item indexes by single index matrix u_i and weight vector W^i.

Then
$$u^i=(u_{i1},u_{i2},\cdots,u_{ik}) \tag{6}$$

Among it,

$$u^i = W^i \cdot (u_{ijk})_{m\times K} = (w_1^i, w_2^i, \cdots, w_m^i)\begin{bmatrix} u_{i11} & u_{i12} & \cdots & u_{i1K} \\ u_{i21} & u_{i22} & \cdots & u_{i2K} \\ \vdots & \vdots & & \vdots \\ u_{im1} & u_{im2} & \cdots & u_{imK} \end{bmatrix} \quad (7)$$

4) Confidence Level Recognition Criteria

Because the appraisal rank is orderly division, so we adopt confidence level recognition criteria. It is supposed that confidence level λ is usually adapted to 0.6 or 0.7.

Order $$k_0 = \min_k [(\sum_{l=1}^{K} u_{il}) \geq \lambda, k = 1, 2, \cdots, k] \quad (8)$$

Then, judging object x_i belongs to the k_0 appraisal rank.

V. Empirical Analysis

A. Rough Set Attribute Reduction

For the initial index system, we investigated 10 logistics enterprises in Han Dan, and attain original data. We have 31 secondary grade indicators as condition attributes, and discretized these original data (as follows Table Ⅱ), then we divided the results into four levels, denoted by $D = \{4, 3, 2, 1\}$, standing for {excellent, good, general, bad}; The enterprise evaluation results are regarded as decision attributes, denoted by $D = \{4, 3, 2, 1\}$, standing for {exceeding satisfied, satisfied, generally satisfied, dissatisfied}. The number of the index is large, so Table Ⅱ only contains a part of the index data.

TABLE II
Enterprise Emergency Logistics Capability Decision Table

	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{21}	I_{22}	I_{23}	I_{24}	I_{25}	I_{31}	…	D
1	1	3	2	2	2	2	2	2	3	3	2	1	…	3
2	3	2	1	2	1	1	1	1	2	3	2	2	…	2
3	2	3	2	3	2	2	2	3	1	3	3	3	…	1
4	4	1	3	4	3	3	3	2	2	2	4	2	…	3
5	4	2	4	2	1	3	3	3	3	2	3	3	…	4
6	1	2	3	1	2	2	2	2	4	2	1	3	…	1
7	2	3	2	3	3	4	4	3	3	3	1	4	…	4
8	1	2	2	3	4	3	4	3	2	4	3	3	…	3
9	3	4	1	2	3	2	2	2	2	1	2	2	…	2
10	4	3	1	1	4	1	1	2	3	1	2	3	…	1

Applying rough set to decision table for attributes reduction, the steps are following:

①Consistency check. By checking, Table I is consistency decision table.

②Attributes reduction. We remove the attributes one by one from attribute set *I*, then if there is not any new unconsistency after removing, we can decide whether the attribute can be removed or not.

Firstly, removing the column which I_{11} belongs to, if there appears the new inconsistency meaning that appears the same lines, so the attribute I_{11} cannot be removed, that is the core attribute. Applying the same method to remove the remaining attributes. By the data analysis we can research the attributes I_{12}, I_{16}, I_{23}, I_{34}, I_{42}, I_{55} can be reduced, and the final decision table consists of the attributes I_{11}, I_{13}, I_{14}, I_{15}, I_{21}, I_{22}, I_{24}, I_{25}, I_{31}, I_{32}, I_{33}, I_{35}, I_{41}, I_{43}, I_{44}, I_{45}, I_{46}, I_{51}, I_{52}, I_{53}, I_{54}, I_{61}, I_{62}, I_{63}, I_{64}.

For the reduction algorithm is so complex, this paper adopts MATLAB to reduce the index table. After reduction, the index system totally includes 25 secondary grade indicators. Now the index system table has no redundant information, also, it is comprehensive, systematic, and has strong operability.

B. The Unascertained Comprehensive Evaluation

According to the above mentioned in the comprehensive evaluation model of unascertained measure, now put Han Dan city 50 logistics enterprises as an example to evaluate. Then make a questionnaire based on reduced index system, and invite experts to grade, the comment space is: {exceeding satisfied, satisfied, generally satisfied, dissatisfied, very dissatisfied}. There are 25 evaluation indexes, every expert only has 10 marks to use, and the 10 marks are distributed on the 5 evaluation grades, finally obtain the scoring average of each index. This marking method is fair and equal, and it also satisfies "nonnegative and bounded nature, additive nature, and normalization" measurement principle.

The single index measurement matrix is as follows: (evaluation objects is set to 1)

$$u_{1jk}^1 = \begin{bmatrix} 0.115 & 0.243 & 0.356 & 0.216 & 0.070 \\ 0.125 & 0.255 & 0.412 & 0.116 & 0.092 \\ 0.211 & 0.321 & 0.196 & 0.165 & 0.107 \\ 0.106 & 0.342 & 0.267 & 0.205 & 0.080 \\ 0.166 & 0.205 & 0.311 & 0.227 & 0.091 \\ 0.168 & 0.244 & 0.324 & 0.163 & 0.101 \\ 0.050 & 0.175 & 0.312 & 0.286 & 0.177 \\ 0.315 & 0.251 & 0.232 & 0.166 & 0.036 \\ 0.081 & 0.153 & 0.252 & 0.324 & 0.190 \\ 0.115 & 0.248 & 0.367 & 0.163 & 0.107 \\ 0.215 & 0.355 & 0.231 & 0.135 & 0.064 \\ 0.106 & 0.157 & 0.413 & 0.257 & 0.067 \\ 0.305 & 0.289 & 0.233 & 0.118 & 0.055 \end{bmatrix}$$

$$u_{1jk}^2 = \begin{bmatrix} 0.176 & 0.211 & 0.273 & 0.265 & 0.075 \\ 0.118 & 0.219 & 0.325 & 0.260 & 0.078 \\ 0.116 & 0.206 & 0.320 & 0.250 & 0.108 \\ 0.215 & 0.478 & 0.115 & 0.107 & 0.085 \\ 0.318 & 0.216 & 0.284 & 0.117 & 0.065 \\ 0.120 & 0.203 & 0.327 & 0.262 & 0.088 \\ 0.176 & 0.218 & 0.315 & 0.140 & 0.151 \\ 0.305 & 0.273 & 0.230 & 0.132 & 0.060 \\ 0.155 & 0.212 & 0.298 & 0.201 & 0.134 \\ 0.109 & 0.165 & 0.313 & 0.287 & 0.126 \\ 0.127 & 0.248 & 0.343 & 0.215 & 0.067 \\ 0.410 & 0.218 & 0.170 & 0.132 & 0.070 \end{bmatrix}$$

According to formula (2) to (5) calculated index weight is as follows:

W^1=(0.0464, 0.0585, 0.0213, 0.0440, 0.0240, 0.0257, 0.0446, 0.0499, 0.0319, 0.0395, 0.0445, 0.0652, 0.0483, 0.0263, 0.0387, 0.0290, 0.0804, 0.0450, 0.0355, 0.0165, 0.0417, 0.0308, 0.0308, 0.0432, 0.0552).

According to formula (7), get the appraisal vector of the object 1:

$$u^1 = W^1 \cdot u_{1jk} = (0.1867, 0.2590, 0.2894, 0.1922, 0.8984).$$

Get λ =0.7, according to formula (8):

When k_0 =3, $0.1867 + 0.2590 + 0.2894 = 0.7351 > 0.7$.

So, from the above results we can conclude that the logistics enterprises emergency logistics capability in unconventional emergencies is in the generally satisfied level. The logistics service enterprises acquire quite high scores in the information processing ability, emergency rescue ability, but low scores relatively in the organization and management ability, ability to support security and logistics costs. Therefore, in future work we should intensify the management, ensure a certain cost and increase the number of emergency equipment, so that we can improve the enterprise emergency logistics capability in unconventional emergencies in the further.

VI. CONCLUSIONS

The paper suggests that more attention must be paid to the emergency management of unexpected events, it is significant to do a good job in emergency work and minimize unnecessary disaster. This paper establishes the index system of emergency logistics capability of enterprises based on the investigation of Han Dan city logistics analysis. Meanwhile the unascertained theory pays attention to the spatial order of the evaluation; it determines the level of the evaluation results by the criterion of degree of confidence. So the evaluation results can be more scientific, accurate and reasonable. A theoretical basis is provided for improving the emergency logistics capability of enterprises.

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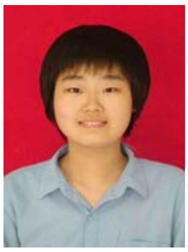
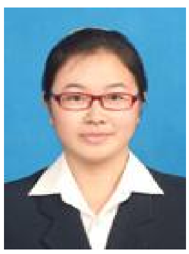
Xiangyang Ren, born in Leting County, Hebei Province, P.R.China, on February 11, 1979. He received his Ph.D in Management Science and Engineering (2009) from China University of Mining and Technology, Beijing, P.R.China.

He has been working in Hebei University of Engineering since June, 2009. Now he is an associate professor. His current research interests include different aspects of artificial intelligence and supply chain management. Published articles: Enterprise Emergency Logistics Capability Index System Construction Based on Rough Set Theory, ICIC Express Letters, Part B: Applications, 2013; Study on Evaluation of Enterprise Emergency Logistics Capacity Based on Rough Set, Logistics Technology, 2013; Study on Benefit Allotment of Agricultural Produce Supply Chain Based on Game Model, Logistics Technology, 2013.



Xue Wen, born in Congtai District, Hebei Province, P.R.China, on June 25, 1989. She received her B.Ms. in Management Science and Engineering (2012) from Hebei University of Technology, Tian Jin, P.R.China. Now she is a graduate student of Logistics Engineering at School of Economics and Management, Hebei University of Engineering, Han Dan, Hebei Province, P.R.China. Her current research interests include different aspects of logistics and supply chain management.



Shu Wang, born in Lulong County, Hebei Province, P.R.China, on November 10, 1987. She received her B.Cs. in Computer Science and Technology (2009) from Hebei University of Technology, Tian Jin, P.R.China. Now she is a graduate student of Logistics Engineering at School of Economics and Management, Hebei University of Engineering, Han Dan, Hebei Province, P.R.China. Her current research interests include different aspects of logistics and supply chain management.

Xiaotong Niu, born in Hanshan District, Hebei Province, P.R.China, on August 31, 1993. Now she is an undergraduate student of Accountancy at School of Economics and Management, Hebei University of Engineering, Han Dan, Hebei Province, P.R.China. Her current research interests include different aspects of financial accounting and financial management.