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Risk assessment on shipping logistics of dangerous chemicals

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ABSTRACT

The basic steps for conducting risk assessment on shipping logistics of dangerous chemicals are first proposed. And then a model for the risk assessment is established, employing the matter-element based method and GAHP Approach, to be used as a reference for formulating corresponding strategies.

Keywords: dangerous chemicals; risk assessment; shipping logistics; matter-element based approach

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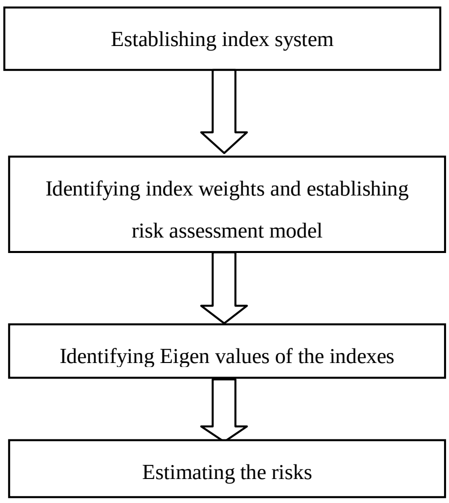
INTRODUCTION

Chemical industry in China witnesses fast development along with continuous economic and social progress and resulting from favorable policies in recent years. Correspondingly, shipment of dangerous chemicals is also developing with a growing speed [1]. However, shipment of dangerous chemicals is of relatively high risk for the special properties of the articles during shipping. And even the society would be affected once an accident occurs. The research, therefore, identifies the risks existing during shipping logistics of dangerous chemicals and conducts a risk assessment for that from the perspective of risk management. The purpose of it is to lower the risks and ensure smooth operation of shipping dangerous chemicals.



Graph 1 Flowchart of risk assessment on shipping logistics of dangerous chemicals

1 Basic procedures of risk assessment on shipping logistics of dangerous chemicals

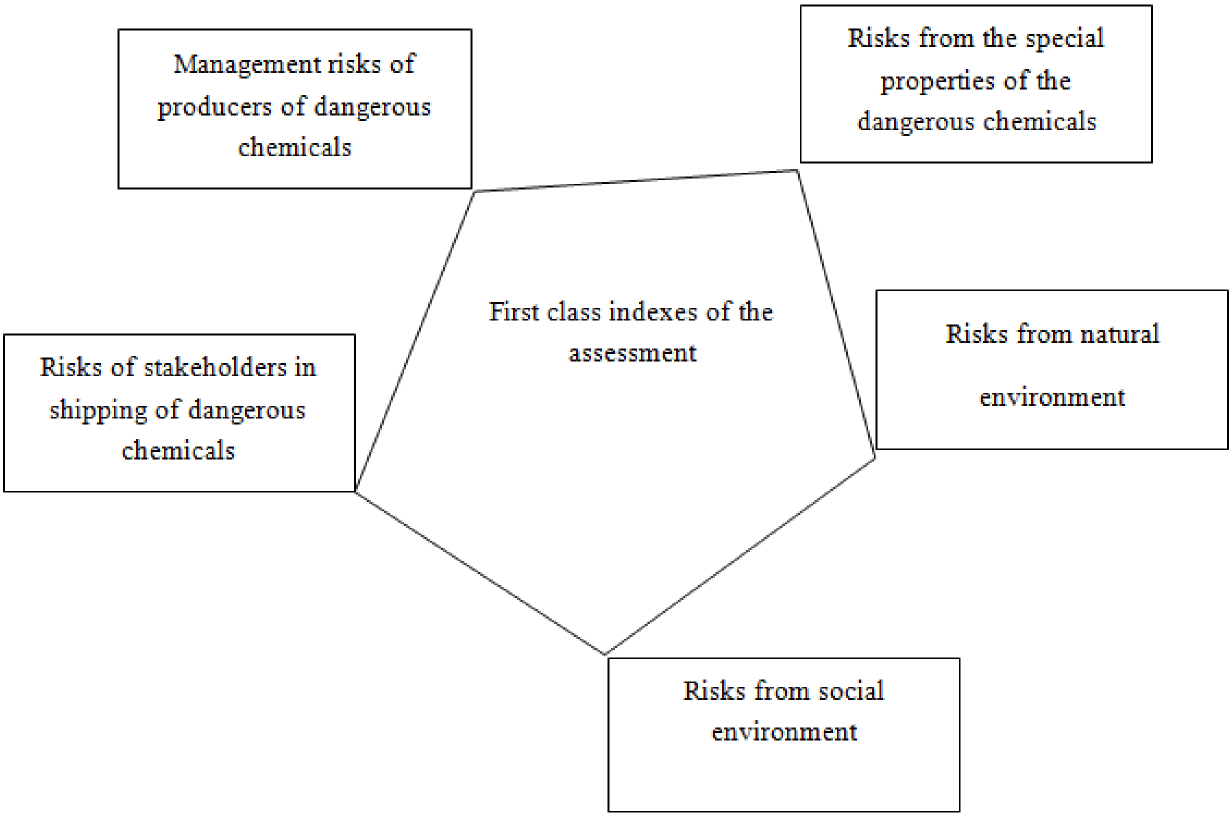
The following procedures are proposed to ensure the validity of the risk assessment. Specifically, an index system is first established for the risk assessment referring to the results of identifying risks on shipping logistics of dangerous chemicals and in compliance with certain principles [2]. A model for the risk assessment is then established employing proper and relevant methods or models. Finally, the Eigen values of various indexes are identified according to the actual conditions and the risks are estimated in a scientific way based on the model previously established. Those data are then to be used as a reference for formulating corresponding strategies for risk control.

The basic procedures for the risk assessment on shipping logistics of dangerous chemicals are illustrated in Graph 1.

2 Establishing index system for the risk assessment

Establishing an index system is given top priority to conduct the risk assessment. In the process, certain principles are recommended to be abided by including scientific principle, representative principle, comparable principle, operational principle and systematic principle so as to promote the establishing of index system of the assessment in a proper way [3]. Moreover, the system shall be a complicated index system with indexes of multi-layers consisting of first and second class indexes rather than a unitary system [4].

First class indexes in the system are presented in Graph 2.



Graph 2 First class indexes in the system for the risk assessment on shipping logistics of dangerous chemicals

Based on the first class index system, the second class index system is established according to the results of identifying risk in shipping logistics of dangerous chemicals to reflect first class indexes. Thus, the index system for risk assessment is formed, as shown in Table 1.

3 Establishing up models for risk assessment of shipping logistics of dangerous chemicals

According to the basic procedures, after completing the index system for risk assessment, the next shall be establishing up models for the assessment.

Many methods are among the choices for conducting risk assessment on shipping logistics of dangerous chemicals, particularly in qualitative evaluation, in which, Systems Science and Decision Making theories can be introduced. Moreover, it is found that each method is of its own merits, demerits and scope of application after a comparison of the methods including Principal Component Analysis, Grey System Theory, Fuzzy Comprehensive Evaluation, Ideal Solution, Matter-element model and Analytical Hierarchy Process [5]. Based on the comparison, an assessment model is proposed to be established with a combination of the Matter-element Approach and Group Analytical Hierarchy Process to promote the research.

Table 1 Index system for risk assessment of shipping logistics of dangerous chemicals

Index	First class index	Second class index
Index system for risk assessment of shipping logistics of dangerous chemicals（O）	Risk from their special properties X_1	Ignitability X_{11}
		Explosiveness X_{12}
		Easy diffusion X_{13}
	Management risk of producers X_2	Logistics safety management system X_{21}
		Human resources of logistics management X_{22}
		Storage security control X_{23}
		Loading security control X_{24}
		Emergency programs and equipment X_{25}
	Risk of stakeholders in shipping X_3	Security management organization of logistics enterprises X_{31}
		Security management system of logistics enterprises X_{32}
		Transportation management system of logistics enterprises X_{33}
		Operation configuration of logistics enterprises X_{34}
		Ship performance of logistics enterprises X_{35}
		Qualification of employees in logistics enterprises X_{36}
		Emergence programs and equipment of logistics enterprises X_{37}
	Risk of natural environment X_4	Risk from navigation waters X_{41}
		Risk from hydrological conditions X_{42}
		Risk from geological conditions X_{43}
		Risk from topographical conditions X_{44}
		Risk from climate conditions X_{45}
	Risk of social environment X_5	Risk from laws and regulations X_{51}
		Risk from supervision and investigation of government X_{52}
		Risk from technological environment X_{53}
		Risk from general public's attitude X_{54}

3.1 Analysis on Scope of Application of Matter-element and GAHP model

The index system of risk assessment itself is a relatively complicated one and entails five major aspects: management risk of producers of dangerous chemicals, risks from the special properties of the dangerous chemicals, risks of stakeholders in shipping of dangerous chemicals, risks from natural environment and risk from social environment. And specifically, there are altogether 24 indexes for risk assessment [6]. Values of a majority of the indexes, however, are obtained through a comprehensive analysis on a subjective basis rather than directly reflected by specific numerals. An assessment model able to deal with complicated issues and analyze both qualitative and quantitative indexes is preferred. It is on the basis of requirements and specific characteristics of shipping of dangerous chemicals.

With a history going back to the 1980s, Matter Element Analysis is an emerging interdisciplinary subject of Systems Science, Cognitive Science and mathematics and also a cross disciplinary subject of natural sciences and humanities with a wide scope of application [7]. Matter Element Analysis presents rules and methods for resolving issues through analysis of matter element and its evolvement. Matter Element Analysis contributes to visualize complicated objects and establish a comprehensive evaluating model. It uses multi-indexes and multi-parameters to present the results with quantitative numerals and reflect the aggregated level of the objects. GAHP is an effective way to identify value weights of indexes evolved from AHP. Traditional AHP is limited to single person decision making, thus problems such as a high degree of subjectivity and a low level of accuracy are inevitable in indentifying value weights [8]. Because GAHP takes multi-person decision making into account, it ensures the accuracy of value weights through accepting suggestions from more people.

The Matter Element Model is based on extension set. It employs Matter Element Transforming Method to alter problems incompatible into compatible so as to reasonably describe the relationship of the internal structures of natural and social phenomena and the varying curves. The value weights of the indexes are calculated using GAHP for the purpose of comprehensive evaluation and sequencing, which is in compliance with the objective and requirement of the risk assessment on shipping logistics of dangerous chemicals. It is thus feasible to introduce Matter Element-GAHP method into the research.

3.2 Constructing a model based on Matter Element-GHAP model for the risk assessment

The procedures for establishing a model based on Matter Element-GHAP model for the risk assessment are as follows.

Step 1: Establishing an index system for the risk assessment

The index system can be referred in Table 1.

Step 2: Identifying value weights of X_i and U_{is} in the index system

Identifying value weights of the indexes in the system is conducted based on GAHP. The experts selected are first required to identify the value weights employing the data using AHP, and then the ultimate result of the value weights is obtained through calculating the arithmetic average of the value weights offered by each expert.

In the process for determining the value weights in the index system, it is presumed that the weight assignment of First-class index X_i is a_i（$i=1,2,\ldots,5$）,and the weight vector $A=(a_1,a_2...,a_5)$ with $a_i \geq 0$ and $\sum_{i=1}^{5} a_i = 1$. Similarly, the Second-class index X_{is} is a_{is} （$i = 1,2,\ldots,5$； $s = 1,2,\ldots, n_i$ ）,the weight vector $A_i = (a_{i1}, a_{i2}, ..., a_{in})$ with $a_{is} \geq 0$ and $\sum_{s=1}^{n_i} a_{is} = 1$.

Step 3: Identifying classical domain and section domain

The risk on shipping logistics of dangerous chemicals is rated into five grades, entailing quite high, fairly high, moderate, fairly low, and quite low. The indexes for assessment are thus divided into five grades correspondingly with the first indicating quite low, the second fairly low, the third moderate, the fourth fairly high and the fifth quite high.

Under the index X_1 representing the risk from the special properties of dangerous chemicals, the classical domain of each grade is presented as $R_{01} = \begin{bmatrix} 1Grade & X_{11} & 0\text{-}20 \\ & X_{12} & 0\text{-}20 \\ & X_{13} & 0\text{-}20 \end{bmatrix}$, $R_{01} = \begin{bmatrix} 2Grade & X_{11} & 20\text{-}40 \\ & X_{12} & 20\text{-}40 \\ & X_{13} & 20\text{-}40 \end{bmatrix}$, $R_{01} = \begin{bmatrix} 3Grade & X_{11} & 40\text{-}60 \\ & X_{12} & 40\text{-}60 \\ & X_{13} & 40\text{-}60 \end{bmatrix}$, $R_{01} = \begin{bmatrix} 4Grade & X_{11} & 60\text{-}80 \\ & X_{12} & 60\text{-}80 \\ & X_{13} & 60\text{-}80 \end{bmatrix}$, $R_{01} = \begin{bmatrix} 5Grade & X_{11} & 80\text{-}100 \\ & X_{12} & 80\text{-}100 \\ & X_{13} & 80\text{-}100 \end{bmatrix}$.

And the section domain $R_{p1} = \begin{bmatrix} X_{11} & 0-100 \\ X_{12} & 0\text{-}100 \\ X_{13} & 0\text{-}100 \end{bmatrix}$, with R_{p1}=[the risk from the special properties of dangerous chemicals].

First class, second class, third class, fourth class, fifth class

The classical domain and section domain of various grades under different indexes can be gained by the analogy.

STEP4: Identifying Matter Element for assessment

The experts invited by producers of dangerous chemicals rated the risks existing in shipping according to the above index system and assessing criteria. And the value u_{in} is obtained through taking an average of the values identified by the experts. The number of Matter Element to be assessed is 6 in the index system. It is presumed that the object to be assessed is P_m (m=0, 1, …, 5) and the results after calculations are presented as R_m, to be referred to as Matter Element to be assessed. Then the Matter Elements to be assessed in the research are as follows.

$$R_0=\begin{bmatrix} p_0 & X_1 & x_1 \\ & X_2 & x_2 \\ & X_3 & x_3 \\ & X_4 & x_4 \\ & X_5 & x_5 \end{bmatrix},\quad R_1=\begin{bmatrix} p_1 & X_{11} & x_{11} \\ & X_{12} & x_{12} \\ & X_{13} & x_{13} \end{bmatrix},\quad R_2=\begin{bmatrix} p_2 & X_{21} & x_{21} \\ & X_{22} & x_{22} \\ & X_{23} & x_{23} \\ & X_{24} & x_{24} \\ & X_{25} & x_{25} \end{bmatrix},\quad R_3=\begin{bmatrix} p_3 & X_{31} & x_{31} \\ & X_{32} & x_{32} \\ & X_{33} & x_{33} \\ & X_{34} & x_{34} \\ & X_{35} & x_{35} \\ & X_{36} & x_{36} \\ & X_{37} & x_{37} \end{bmatrix},$$

$$R_4=\begin{bmatrix} p_4 & X_{41} & x_{41} \\ & X_{42} & x_{42} \\ & X_{43} & x_{43} \\ & X_{44} & x_{44} \\ & X_{45} & x_{45} \end{bmatrix},\quad R_5=\begin{bmatrix} p_5 & X_{51} & x_{51} \\ & X_{52} & x_{52} \\ & X_{53} & x_{53} \\ & X_{54} & x_{54} \end{bmatrix}。$$

Among them,
R_0—— the Matter Element for risk assessment on shipping logistics of dangerous chemicals;
R_1—— the Matter Element for assessment on risks from the special properties of dangerous chemicals;
R_2—— the Matter Element for assessment on management risks of producers of dangerous chemicals;
R_3——the Matter Element for assessment on risks of stakeholders in shipping;
R_4—— the Matter Element for assessment on risks from natural environment;
R_5——the Matter Element for assessment on risks from social environment.
x_i（i=1, 2, …, 5）—— the weighted value of indexes in the criteria.

Step 6: Identifying correlation between indexes of the Matter Element to be assessed on various grades j
It is presumed,

$$K_j(x_i)=\begin{cases}\dfrac{\rho(x_i,x_{0ji})}{\rho(x_i,\ x_{pi})-\rho(x_i,x_{0ji})}, & \text{当}\rho(x_i,\ x_{pi})-\rho(x_i,x_{0ji})\neq 0\text{时} \\ -\rho(x_i,x_{0ji})-1, & \text{当}\rho(x_i,\ x_{pi})-\rho(x_i,x_{0ji})=0\text{时}\end{cases}$$, in which

$$\rho(x_i,x_{0ji})=\left|x_i-\frac{1}{2}(a_{0ji}+b_{0ji})\right|-\frac{1}{2}(b_{0ji}-a_{0ji}) \quad \text{and} \quad \rho(x_i,x_{pi})=\left|x_i-\frac{1}{2}(a_{pi}+b_{pi})\right|-\frac{1}{2}(b_{pi}-a_{pi}).$$

In the above formulas, $\rho(x_i,x_{0ji})$ represents the distance between x_i to x_{0ji}, and $\rho(x_i,x_{pi})$ the distance between x_i to the section x_{pi}.

Step 7: Calculating correlation of P_m **on various grades** j

If the weight coefficient of X_i is a_i and $\sum_{i=1}^{n}a_i=1$, then $K_j(p)=\sum_{i=1}^{n}a_iK_j(x_i)$, in which $K_j(p)$ represents the combination value of correlation on various grades of the indexes with regard to the value weights of the indexes. The formula is not only a model for calculating correlation of j in various sections of the object to be assessed, but also a model for calculating correlation j of the object as a whole.

Step 8: Rating

Given $K_{j_0}(p)=\max_{j\in(1,2,\ldots,m)}K_j(p)$, P_m is rated j_0.

CONCLUSION

A risk assessment model for shipping logistics of dangerous chemicals is established. It is based on Matter Element

Approach and GAHP for the purpose of making an overall and comprehensive assessment on shipping of dangerous chemicals. Meanwhile, the model contributes to reflect the risks by numerals in five aspects including management risk of producers of dangerous chemicals, risk from the special properties of the dangerous chemicals, risk of stakeholders in shipping of dangerous chemicals, risk from natural environment and risk from social environment. So that it is beneficial for producers of dangerous chemicals to understand systematically the risks during shipping of such articles. It is also useful to make corresponding strategies targeting to those risks to ensure smooth operation and development of the shipping of dangerous chemicals.

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