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Risk Analysis of Chemical Industry Based on Group Consensus Decision Making Method

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As chemical industry has developed rapidly, some problems for our society have appeared, especially the problems related to chemical risk management. Because density of dangerous chemical products is relative high and components of chemical products are relative complex, it may increase the probability that dangerous chemical risk happens. Thus, for chemical enterprises, they not only need to improve economical level, but also need to control risk management. Meanwhile, although the existing studies have been focused on risk management of chemical industry, there are still some problems such as a rational method to assess chemical risk. In order to overcome these problems, this paper develops a new chemical risk assessment method based on group decision making method by considering group consensus of all chemical experts according to an advanced threshold. 2-tuple fuzzy linguistic term set is introduced to help the chemical experts express their risk assessments and final result analysis demonstrates that the proposed method is applicability in chemical risk assessment.

1. Introduction

Recently, as chemical industry has developed rapidly, many chemical industrial zones appear in different cities which have high efficiency of using energy and a little pollution (Liu, 2011). This can further promote the development of regional economy. However, the rapid development of chemical industry also brings some problems for our society (Ge et al., 2016). The big one is the chemical risk. For example, in chemical industrial zone, density of dangerous chemical products is relative high and components of chemical products are relative complex. That may increase the probability that dangerous chemical risk happens. More important, due to the distance between basic facilities is small, once a dangerous chemical product happens such as leak of toxic substance or fire explosion, the result may be severe (Huang et al., 2011). In 2001, Lutz chemical plant in France has an explosion which leads to the deaths of more than 30 people and more than 2500 people were injured. The buildings within 2 km were severely damaged. In 2008, melamine in Sanlu milk powder results in damage of many children and further influences their future life. 2012, a chemical enterprise pours the poisonous chemical waste into a lake and finally results in severe contamination of the lake and local environment. From the above analysis, we can see that these accidents are closely related to the risk management of the chemical enterprises. Many existing chemical enterprises pursue economic benefits but ignore the consequence generated from the risk (Lin and Kong, 2008). Chemical industry as an important industry in our country is a big urge to promote the development of our society. Thus, for chemical enterprises, they not only need to improve economical level, but also need to control risk management (Jiang, 2009).

Cheng (2012) takes a real chemical enterprise for an example to analyse the main reason why the chemical risk frequently happens, construct a risk management framework of chemical enterprises and further develop some necessary measures to guarantee operation of risk management. Tian (2015) introduced AHP to assess the risk index of different chemical enterprises to construct three-dimensional index system to help chemical enterprise effectively identify their risk and further adopt corresponding behaviour. Gao et al. (2009) developed risk sensitive analysis method to evaluate environmental risk of petroleum chemical industry based on

regional environment to help the decision maker make rational chemical decision related to chemical enterprise. Although the existing studies have been focused on risk management of chemical industry, there are still some problems such as a rational method to assess chemical risk (Zhou, 2016).
In order to overcome these problems, in this paper, we pay attention to develop a new chemical risk assessment method based on group decision making method. As mentioned above, chemical risk management is very complex and thus a single expert may not make correct decisions. So, it is necessary to invite a group of many experts to provide their decisions related to chemical risk. In order to make each expert satisfy the final chemical risk decisions, group consensus of all chemical experts is defined. Before that, 2-tuple fuzzy linguistic term set is introduced to help the chemical experts express their risk assessments because 2-TFLTS is considered as a popular way to complete it (Herrera and Martinez, 2000). Result analysis demonstrates that the proposed method is applicability in chemical risk assessment.
The rest of the content is demonstrated. Section 2 gives the proposed group consensus decision making method for chemical risk assessment involving in 2-TFLTS risk expressions, risk decision aggregation and the definition of group consensus in chemical group related to chemical risk management. Sections 3 and 4 give areal case to apply the proposed method to solve chemical risk assessment problem. Section 5 concludes the paper and gives the future study.

2. Group consensus decision making method

As mentioned above, risk of chemical industry is complex and difficult to be completely solved by a single expert. Thus, group consensus based risk decision making method related to chemical industry is developed in the following.

2.1 Decision information related to risk analysis

Due to different chemical knowledge background, industrial engineering experience and risk attitude about chemical problem, the experts may feel difficulty to exactly provide decision information related to chemical risk. Thus, in this paper, in order to deal with risk analysis of chemical industry, we introduce 2-tuple fuzzy linguistic term set which can be simply called 2-TFLTS.Let $TL = \{l_b | b = 0, 1, ..., a\}$ be a linguistic term representing set (Dong et al. 2008). The term l_b is used to denote a linguistic variable expressed by experts and a is a positive value. The linguistic term representing set TL is also named as linguistic scale. Here, the set is often considered as ordered: $l_b > l_c$ if and only if $b > c$. Therefore, there exists a negation operator: $Neg(l_b) = l_{-b}$. In particular, $Neg(l_0) = l_0$. The number of all linguistic terms in set TL is named as the cardinality of TL. Then, based on the above basic concepts, 2-TFLTS can be defined by Herrera and Martinez (2000) as follows to help chemical experts provide decision information.
Definition 1. Let $TL = \{l_b | b = 0, 1, ..., a\}$ be a basic linguistic term set and $\delta \in [0, a]$be the aggregation interval number in the granularity of the set TL. Let η = round(δ) and $\varphi = \delta - b$ be two precise value and can satisfy that $b \in [0, a]$ and $\varphi \in [-0.5, 0.5)$. Thus φ is considered as a symbolic translation with the so called rounding operation.
The above definition develops 2-TFLTS by using 2-tuples (l_b, φ) where $l_b \in$ TL and $\varphi \in [-0.5, 0.5)$.
Definition 2. Let $TL = \{l_b | b = 0, 1, ..., a\}$ be a linguistic term set and $\delta \in [0, a]$be an aggregation interval number, then the 2-tuple that can provide the equivalent information to δ is generated with a transformation relationship as:

$\Gamma : [0, a] \rightarrow TL \times [-0.5, 0.5)$,

$$\Gamma(\delta) = (l_b, \varphi) \text{ with } \begin{cases} l_b, & b = round(\delta) \\ \varphi = \delta - b, & \varphi \in [-0.5, 0.5) \end{cases}$$

where Γ means a mapping from one to one. Round(·) denotes the basic round operation, $l_b$has the relative close index term to δ, and $\varphi$is the precise value in the symbolic translation interval. In order to simplify, the range of function £ is denoted as $\overline{TL}$. Then, we have Γ^{-1}: $\overline{TL} \times [-0.5, 0.5) \rightarrow [0, a]$, $\Gamma^{-1}(l_b, \varphi) = \varphi + b = \delta$.
Obviously, when $\varphi = 0$, a 2-TFLTSwill reduce to an original LTS. $l_b \in TL \Rightarrow (l_b, 0)$
Then, in order to obtain the final result, the comparison between two 2-TFLTS is proposed by Dong et al. (2015) and Herrera and Martinez (2000).
Definition 3. Suppose (l_b, φ_1) and (l_c, φ_2) are two 2-TFLTSs, then they can be compared by using the following rule:

(1) when $b<c$, then (l_b, φ_1) is considered as smaller than (l_c, φ_2);

(2) when *b*= *c*, then

1) if φ_1=φ_2, then (l_b, φ_1) and (l_c, φ_2) can hols the same decision information;

2) if φ_1<φ_2, then (l_b, φ_1) is considered as smaller than (l_c, φ_2);

3) if φ_1>φ_2, then (l_b, φ_1) is considered as bigger than (l_c, φ_2).

A 2-TFLTS negation operator can be provided as

$$Neg(l_b,\varphi)=\Gamma\left(a-\left(\Gamma^{-1}(l_b,\varphi)\right)\right)$$

Then, the basic operational rule can be further developed as follows in order to aggregate chemical risk decision information.

(1) $l_b \oplus l_c = l_{b+c}$;

(2) $l_b \oplus l_c = l_c \oplus l_b$;

(3) $\varepsilon l_b = l_{\varepsilon b}$;

(4) $(\varepsilon_1+\varepsilon_2)l_b = \varepsilon_1 l_b \oplus \varepsilon_2 l_b$;

(5) $\varepsilon(l_b \oplus l_c) = \varepsilon l_c \oplus \varepsilon l_b$.

For chemical risk assessment problem, the decision matrix by using 2-TFLTS can be constructed in Eq. (1) where all the risk decision information m_{io}(i=1, 2, …AT; o=1,2,…AT) are2-TFLTS, provided by the invited chemical experts.

$$Matrix=\begin{pmatrix} m_{11} & m_{12} & \cdots & m_{1o} \\ m_{21} & m_{22} & \cdots & m_{2o} \\ \vdots & \vdots & \ddots & \vdots \\ m_{i1} & \cdots & \cdots & m_{io} \end{pmatrix} \tag{1}$$

Definition 4. Suppose *M* = {(l_1, φ_1), ..., (l_n, φ_n)}area group of2-TFLTSs. Then the 2-TFLTS arithmetic average operator can be computed as

$$\text{AVO} = \Gamma\left(\sum_{i=1}^{n}\frac{1}{n}\Gamma^{-1}(l_i,\varphi_i)\right) = \Gamma\left(\frac{1}{n}\sum_{i=1}^{n}\varphi_i\right) \tag{2}$$

Definition 5. Suppose *M* = {(l_1, φ_1), ..., (l_n, φ_n)}area group of2-TFLTSs. Then the 2-TFLTS weighted arithmetic average operator can be computed as

$$\text{WAVO} = \Gamma\left(\sum_{i=1}^{n}w_i\Gamma^{-1}(l_i,\varphi_i)\right) = \Gamma\left(\sum_{i=1}^{n}w_i\varphi_i\right) \tag{3}$$

where w_i is the weight of 2-TFLTSs set M.

2.2 Group consensus measure in risk analysis

Consensus in this paper of group decision making means the full and unanimous agreement of risk decision judgement provided by all chemical experts related to all possible chemical enterprises which are considered as chemical alternatives in this risk assessment. Thus, the similarity of risk decision information is used to measure consensus in chemical risk assessment.
First of all, suppose (l_b, φ_1) and (l_c, φ_2) are two 2-TFLTSs, the similarity between them on each attribute could be defined in the following,

$$Simi\left((l_b,\varphi_b),(l_c,\varphi_c)\right)=1-\frac{\left|\Gamma^{-1}\left((l_b,\varphi_b)\right)-\Gamma^{-1}\left((l_c,\varphi_c)\right)\right|}{a+1} \tag{4}$$

Then, for each decision assessment of each expert on each attribute, its closeness measure can be defined, which is a basis of group consensus:

$$CM^t{}_{io} = \frac{\sum_{y=1,y\neq t}^{T} simi((l^t{}_{io},\varphi_t),(l^y{}_{io},\varphi_y))}{T-1} \tag{5}$$

From Eq. (8), the group consensus in chemical risk assessment group decision making problem can be measured as

$$GG_{io} = \frac{\sum_{t=1}^{T} CM^t{}_{io}}{T} \tag{6}$$

where a threshold will be given in advance.

(1) If $GG_{io} > \overset{\leftrightarrow}{GG}$, then risk assessment can be considered as reaching group consensus in this attribute.

(2)If $GG_{io} < \overset{\leftrightarrow}{GG}$, then risk assessment can be considered as not reaching group consensus in this attribute and may be considered to make experts provide risk assessment again to help them reach group consensus.

3. The first round of risk analysis of chemical enterprises

After the proposed group consensus for chemical risk assessment is introduced, we use this method to assess three chemical enterprises denoted by CE1, CE2 and CE3. Then, by interviewing with the chemical managers and investigating relevant materials, four attributes are selected which are production risk, transportation risk, operation risk and environment risk denoted by RA1, RA2, RA3 and RA4. Three experts from chemical enterprises are invited as the experts to provide the risk assessment and risk preferences for this risk assessment problem based on $TL = \{l_0, l_1, ..., l_4\}$ = {very poor, poor, medium, good, very good}. These risk assessments are demonstrated in Table 1 to Table 3.

Table 1: Risk assessments of expert 1

	RA1	RA2	RA3	RA4
CE1	{*l*(poor), 0.2}	{*l*(medium), 0.1}	{*l*(good), 0.4}	{*l*(medium), 0.3}
CE2	{*l*(good), 0.3}	{*l*(poor), 0.3}	{*l*(good), 0.3}	{*l*(good), 0.2}
CE3	{*l*(medium), -0.1}	{*l*(poor), 0.2}	{*l*(very poor), 0.3}	{*l*(very good), -0.3}

Table 2: Risk assessments of expert 2

	RA1	RA2	RA3	RA4
CE1	{*l*(good), 0.3}	{*l*(poor), -0.2}	{*l*(very good), 0.3}	{*l*(poor), 0.1}
CE2	{*l*(poor), 0.4}	{*l*(very poor), 0.4}	{*l*(poor), 0.1}	{*l*(good), 0.1}
CE3	{*l*(medium), 0.2}	{*l*(good), 0.3}	{*l*(poor), -0.2}	{*l*(good), 0.2}

Table 3: Risk assessments of expert 3

	RA1	RA2	RA3	RA4
CE1	{*l*(very good), -0.4}	{*l*(good), 0.2}	{*l*(very poor), 0.4}	{*l*(poor), 0.2}
CE2	{*l*(very poor), 0.1}	{*l*(good), 0.2}	{*l*(very poor), 0.2}	{*l*(medium), 0.3}
CE3	{*l*(good), -0.2}	{*l*(good), 0.3}	{*l*(poor), 0.4}	{*l*(very poor), 0.3}

After risk assessments are generated, the group consensus can be obtained according to Section 2.2. The procedure to assess chemical risk in this paper is illustrated in Figure 1.

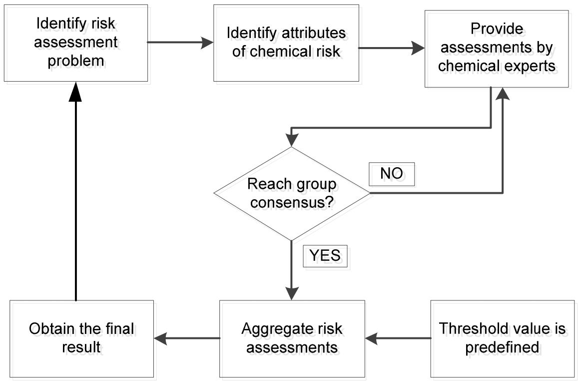

Figure 1: The procedure of evaluating chemical risk of chemical enterprises

4. The second round of risk analysis of chemical enterprises

Because group consensus in the first round has not reached the predefined threshold, then the chemical experts should provide their risk assessments again in Table 4 to Table 6.

Table 4: Risk assessments of expert 1 in the second round

	RA1	RA2	RA3	RA4
CE1	{*l*(medium), 0.2}	{*l*(good), 0.1}	{*l*(good), 0.4}	{*l*(medium), 0.3}
CE2	{*l*(good), 0.3}	{*l*(good), 0.3}	{*l*(medium), 0.3}	{*l*(good), 0.2}
CE3	{*l*(medium), -0.1}	{*l*(good), 0.2}	{*l*(very poor), 0.3}	{*l*(very good), -0.3}

Table 5: Risk assessments of expert 2 in the second round

	RA1	RA2	RA3	RA4
CE1	{*l*(good), 0.3}	{*l*(medium), 0.2}	{*l*(very good), 0.3}	{*l*(poor), 0.1}
CE2	{*l*(medium), 0.4}	{*l*(good), 0.4}	{*l*(very good), 0.1}	{*l*(poor), 0.1}
CE3	{*l*(poor), 0.2}	{*l*(medium), 0.3}	{*l*(poor), 0.2}	{*l*(good), 0.2}

Table 6: Risk assessments of expert 3 in the second round

	RA1	RA2	RA3	RA4
CE1	{*l*(good), 0.2}	{*l*(good), 0.2}	{*l*(good), 0.4}	{*l*(very poor), 0.2}
CE2	{*l*(poor), 0.1}	{*l*(good), 0.2}	{*l*(good), 0.2}	{*l*(medium), 0.3}
CE3	{*l*(medium), 0.2}	{*l*(medium), 0.3}	{*l*(poor), 0.4}	{*l*(medium), 0.3}

After that, the group consensus has been reaching the advanced threshold. Then, the risk assessments are aggregated and final result is generated as: A1>A2>A3.

5. Conclusions and future study

As chemical industry has developed rapidly, some problems for our society have appeared, especially the problems related to chemical risk management. Because density of dangerous chemical products is relative high and components of chemical products are relative complex, it may increase the probability that dangerous chemical risk happens. Thus, for chemical enterprises, they not only need to improve economical level, but also need to control risk management. Meanwhile, although the existing studies have been focused on risk management of chemical industry, there are still some problems such as a rational method to assess chemical risk. In order to overcome these problems, this paper develops a new chemical risk assessment method based on group decision making method by considering group consensus of all chemical experts according to an advanced threshold. 2-tuple fuzzy linguistic term set is introduced to help the chemical experts express their risk assessments and final result analysis demonstrates that the proposed method is applicability in chemical risk assessment.

In the future, more complex information expressions will be introduced in chemical risk assessment to be compared with 2-TFLTS. In addition, the result in sections 3 and 4 will be further analysed by the manager to help them improve chemical risk management level which has been proven that it is important for the development of a chemical enterprise.

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