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# Assessment of Enterprise Value in Chemical Industry by Using Fuzzy Decision Making Method

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Enterprise value as an important index to compare different enterprises has attracted much attention from academic and practical fields, which could denote the value that an enterprise can create and has been widely applied venture investment, financing, enterprise annexation and so on. It is worth to note that in chemical industry, enterprise value is different to other general enterprises. Risk and safety should be highlighted here. In this paper, in order to evaluate value of a chemical enterprise objectively and scientifically, we develop a fuzzy decision making method based on hesitant fuzzy information. Based on this hesitant fuzzy model, similarity measure is introduced to aggregate hesitant fuzzy assessments provided by the decision maker and generates a final optimal enterprise whose value is the best one in all evaluated enterprises. The advantages and disadvantages are also analysed in a simulation experiment. In the future, this proposed method may be extended to more chemical enterprises and help them improve their enterprise value to achieve high level of competitiveness.

## 1. Introduction

Over the past decade, the number of chemical enterprises is increasing with the increase of the industrial level in China. This phenomenon has further improved the development of chemical enterprises. However, a challenge has been appeared here. That is, many accidents especially tremendous accidents frequently happen (Fu, 2007). For example, fire, explosion and secondary environmental pollution may happen in this situation. These will influence on the management of chemical enterprises. In particularly, value assessment should consider not only the common attributes of an enterprises such as cost, service, brand and so on, but also security and the capability of handling emergency accidents (Li et al., 2011).

Enterprise value denotes the value that an enterprise can create, which has been widely applied venture investment, financing, enterprise annexation and so on (Krishna, 2016; Xu, 2014). In theory, enterprise value mainly indicates the possible future value generated from the value of the existing asset and corresponding resources (Zhang, 2010). It reflects the core competitiveness of an enterprises and the overall value of an enterprise. Under the condition that the enterprise can be operated continuously, the overall value of the enterprise integrated from individual assets should be bigger than the simple sum of individual assets (Villa et al., 2016). The management capability, operation of assets, intangible assets and technological level of staff should be reflected in the overall value of the enterprise (Liu 2015; Li et al., 2011). In addition, the value of an enterprise should reflect not only the existing value but also the potential value. It is worth mentioning that the potential value can usually be transformed into the existing value in specific time in the future. Thus, it is important for an enterprise to evaluate their value by considering the mentioned factors and using different methods (Shi, 2015). In general, value assessment of an enterprise includes some characteristics such as integrity, continue operation, predictability, dynamic, risk and so on. These aspects may influence on the results of value assessment (Yang, 2014). Up to now, discounted cash flow and economic value added are two typical methods to evaluate value of an enterprise. Li et al., (2011) analysed these two methods and pointed out these two methods are very objective in value assessment. However, these methods are developed from the perspective of finance. Thus, they are easy to focus on economic level of an enterprise. Then, we reconstruct attribute system to evaluate value of an enterprise.

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In order to copy with this problem, fuzzy decision making method is introduced in this paper. Fuzzy set proposed by Zadeh (1965) can be used to characterize uncertain experts' information by using a function called membership degree function belonging to [0, 1]. Membership degree means that the degree that the expert prefers to this alternative. After that, many different extensions of fuzzy set have been developed by different researchers such as interval-valued fuzzy numbers, intuitionistic fuzzy sets and hesitant fuzzy sets. Here, hesitant fuzzy sets allow experts express several degrees that he prefers to this alternative simultaneously (Liao and Xu 2014). That is, hesitant fuzzy information is more uncertain than classical fuzzy information. Torra (2010) provided some basic concepts and operational law of hesitant fuzzy sets. In order to aggregate experts' hesitant fuzzy information, many aggregation operators are developed by many researchers (). For example, Liao and Xu extended hesitant fuzzy aggregation operators to hybrid weighted aggregation operations and used them to deal with a real decision making problem. Farhadinaia (2016) gave a new hesitant fuzzy set ranking method to handle hesitant fuzzy multiple criterion decision making problems and proven this method is better than the existing ranking techniques.
Thus, this paper introduces hesitant fuzzy set to express relative assessments related to value assessment of chemical enterprises provided by the decision maker under uncertain environment. Before value assessment is conducted, the characteristics of chemical enterprises are analysed firstly. In addition, by interviewing with relevant managers in some chemical enterprises and consulting with some materials, ten attributes are selected which are customer value, innovation, intangible assets, risk, option value, business position, core strategy, service, revenue, profit potential. After that, in order to combine hesitant fuzzy information with attribute weights, similarity measure as a useful tool is developed in this paper. Corresponding weighted similarity measure between two hesitant fuzzy sets is defined. Then, best solution can be selected by constructing generalize TOPSIS model. Here, positive ideal solution and negative ideal solution firstly provided. A parameter to balance these two solutions is also given by the decision maker. Simulation experiment is conducted by the developed hesitant fuzzy model. The rest of this paper is constructed as follows. Section 2 provides the main characteristics of chemical enterprises and thus constructs attribute system. Section 3 develops concepts of hesitant fuzzy sets and similarity measure based this information is also proposed. Section 4 conducts a simulation experiment. Section 5 concludes the whole paper and points out the future work.

## 2. The description of chemical enterprise value

The supply chain of chemical industry is demonstrated and multiple tiers of suppliers are described.
At the beginning, value assessment of an enterprise is developed to help shareholder realize their value. Now, value assessment is for improving sustainability of an enterprise and maximizing the whole value of an enterprise including the shareholder's value. On the one hand, chemical enterprise can contributes to the development of the departments of social economy. On the other hand, chemical enterprise is the main source of industrial pollution. The number, sort and virulence of pollutant in chemical enterprises is far more complex than other enterprises. In general, chemical enterprises can be divided into basic chemical, petrochemical industry and chemical fiber. Table 1 provides corresponding attributes in value assessment.

*Table 1: Explanation of attribute system*

| | Explanation | | Explanation |
|---|---|---|---|
| 1 | customer value | 6 | business position |
| 2 | innovation | 7 | core strategy |
| 3 | intangible assets | 8 | service |
| 4 | risk | 9 | revenue |
| 5 | sustainability | 10 | profit potential |

## 3. Hesitant fuzzy set based decision making

According to Introduction, hesitant fuzzy set based decision making method is introduced in this paper. Thus, in this section, the concepts of hesitant fuzzy set, their information combination and comparison method will be demonstrated.

### 3.1 Hesitant fuzzy set

To copy with a practical problem, hesitant fuzzy set is very useful and effective tool in many styles of information expressions. The definition is given in the following.
Definition 1:

Given a fixed set denoted by A = {$a_1$, $a_2$, ..., $a_n$} and membership functions denoted by Q = {$q_1$, $q_2$, ..., $q_n$}, $q_i \in$ Q is called membership degree in this set. Then, hesitant fuzzy set is defined as

$$HE = \{\langle a, h_Q(a)\rangle | a \in A\} \quad (1)$$

where

$$h_Q(a) = \cup_{q \in Q} \{q(a)\} \quad (2)$$

$h_Q$(a) is limited to [0, 1] which denotes possible membership degrees related to the membership function $Q$ in the set $A$. In order to be simply applied in real cases, $h_Q$(a) is also called hesitant fuzzy element in a hesitant fuzzy set.

Then, the operational law of hesitant fuzzy elements can be provided as follows.

Definition 2:

Suppose $h_u$, $h_v$, denotetwo hesitant fuzzy elements, the operations of hesitant fuzzy elements $h_u$, $h_v$can be defined

(1) $h_u \oplus h_v = \bigcup_{q_u \in h_u, q_v \in h_v} \{q_u + q_v - q_u q_v\}$;

(2) $h_u \otimes h_v = \bigcup_{q_u \in h_u, q_v \in h_v} \{q_u q_v\}$;

(3) $h_u^{\delta} = \bigcup_{q_u \in h_u} \{q_u^{\delta}\}$;

(4) $\delta h_u = \bigcup_{q_u \in h_u} \{1 - (1 - q_u)^{\delta}\}$;

(5) $h_u \oplus h_v = h_v \oplus h_u$.

### 3.2 Similarity measure

Besides many existing operators of hesitant fuzzy sets, distance measure and similarity measure are two flexible tool to portray deviation or closeness among different hesitant fuzzy sets and is introduced in this section to help aggregate decision information on different attributes.

Definition 3:

Suppose $h_u$, $h_v$ denote three hesitant fuzzy elements, then the similarity measure between $h_u$ and $h_v$ denoted by Sim($h_u$, $h_v$) should satisfy

(1) $0 \le Sim(h_u, h_v) \le 1$

(2) $Sim(h_u, h_v) = 1,\ \text{if and only if}\ h_u = h_v$

(3) $Sim(h_u, h_v) = Sim(h_v, h_u)$

Before similarity measure between hesitant fuzzy elements is proposed, a challenge related to hesitant fuzzy element should be firstly solved.

In general, for different hesitant fuzzy elements, the number of possible membership degrees in these elements may not be same. Thus, a problem should be solved. That is how to balance these different lengths of these hesitant fuzzy elements. That means $len(h_u) \neq len(h_v)$. First of all, $len = max(len(h_v), len(h_u))$. Secondly, the shorter one should be extended to be as the same as the longer one. Here, it should be noted that the larger value or the smaller value can be selected. If the decision maker selects the larger value, it means the decision maker is optimistic. If the smaller value is selected, it means that the decision maker is pessimistic. The risk attitude of the decision maker can be obtained by interviewing with them or sending them questionnaires.

Example 1. Suppose $h_u$ = {0.1, 0.2, 0.3}, $h_v$ = {0.2, 0.3} are two hesitant fuzzy elements, the $h_v$ is the shorter one compared with $h_u$. By interviewing with the decision maker, he is considered as pessimistic. Then, $h_v$ = {0.2, 0.2, 0.3}. If the decision maker is optimistic, $h_v$ = {0.2, 0.3, 0.3}.

After all hesitant fuzzy elements have the same length, the similarity measure between them can be defined in the following.

Definition 4:

Suppose $h_u$, $h_v$ denote three hesitant fuzzy elements, then the similarity measure between $h_u$ and $h_v$ denoted by Sim($h_u$, $h_v$) is defined

$$Sim(h_u,h_v)=\frac{\frac{1}{len}\sum_{p=1}^{len}q_{u(p)}\cdot q_{v(p)}}{\left(\frac{1}{len}\sum_{p=1}^{len}\left(q_{u(p)}\right)^2\right)^{1/2}\left(\frac{1}{len}\sum_{p=1}^{len}\left(q_{v(p)}\right)^2\right)^{1/2}} \tag{3}$$

where $Sim(h_u,h_v)\in[0,1]$.

Based on Definition 4, if there are two hesitant fuzzy sets including several hesitant fuzzy elements, then the similarity between these two sets are defined as follows.

Definition 5.

Suppose $HE_1=\{\langle x,h_1(x_i)\rangle|x\in X\}$ where $h_1(x_i)$= {$q_{1i1}$, $q_{1i2}$, ..., $q_{1ilen(1)}$} and $HE_2=\{\langle x,h_2(x_i)\rangle|x\in X\}$ where $h_2(x_i)$ = {$q_{2i1}$, $q_{2i2}$, ..., $q_{2ilen(1)}$} denote two hesitant fuzzy sets, then the similarity measure between $HE_1$ and $HE_2$ is defined as

$$Sim(HE_1,HE_2)=\frac{\sum_{i=1}^{n}\frac{1}{len}\sum_{p=1}^{len}q_{1(p)(i)}\cdot q_{2(p)(i)}}{\left(\sum_{i=1}^{n}\frac{1}{len}\sum_{p=1}^{len}\left(q_{1(p)(i)}\right)^2\right)^{1/2}\left(\sum_{i=1}^{n}\frac{1}{len}\sum_{p=1}^{len}\left(q_{2(p)(i)}\right)^2\right)^{1/2}} \tag{4}$$

Definition 6.

Suppose $HE_1=\{\langle x,h_1(x_i)\rangle|x\in X\}$ where $h_1(x_i)$ = {$q_{1i1}$, $q_{1i2}$, ..., $q_{1ilen(1)}$} and $HE_2=\{\langle x,h_2(x_i)\rangle|x\in X\}$ where $h_2(x_i)$ = {$q_{2i1}$, $q_{2i2}$, ..., $q_{2ilen(1)}$} denote two hesitant fuzzy sets, then the weighted similarity measure between $HE_1$ and $HE_2$ is defined as

$$Sim(HE_1,HE_2)=\frac{\sum_{i=1}^{n}w_i\frac{1}{len}\sum_{p=1}^{len}q_{1(p)(i)}\cdot q_{2(p)(i)}}{\left(\sum_{i=1}^{n}w_i\frac{1}{len}\sum_{p=1}^{len}\left(q_{1(p)(i)}\right)^2\right)^{1/2}\left(\sum_{i=1}^{n}w_i\frac{1}{len}\sum_{p=1}^{len}\left(q_{2(p)(i)}\right)^2\right)^{1/2}} \tag{5}$$

Example 1. Suppose $h_u$ = {0.1, 0.2, 0.3}, $h_v$ = {0.2, 0.3} are two hesitant fuzzy elements, the similarity measure between them can be calculated as

$$Sim(h_u,h_v)=\frac{\frac{1}{3}(0.1\times0.2+0.2\times0.2+0.3\times0.3)}{\left(\frac{1}{3}(0.1\times0.1+0.2\times0.2+0.3\times0.3)\right)^{1/2}\times\left(\frac{1}{3}(0.2\times0.2+0.2\times0.2+0.3\times0.3)\right)^{1/2}}$$

### 3.3 Similarity measure based generalized TOPSIS method

After similarity measure is proposed, the similarity measure based generalized TOPSIS method is further developed in this section.

Firstly of all, a positive ideal solution is set to $HE^*$= max $h$ and a negative idealsolution is set to $HE^{\#}$= min $h$ .Then, the closeness coefficient can be calculated as

$$Close(HE)=\frac{\alpha Sim\left(HE,HE^{\#}\right)}{\alpha Sim\left(HE,HE^{\#}\right)+(1-\alpha)Sim\left(HE,HE^{*}\right)} \tag{6}$$

Where $Close(HE)\in[0,1]$. The value of $Close(HE)$ is bigger, the better the alternative HE is. Thus, Eq(6) can be used to compare different alternatives in this paper. $\alpha$ is a parameter to balance the positive ideal solution and negative ideal solution. If the decision maker prefers to negative ideal solution, $\alpha$may be given larger value.

## 4. Simulation experiment

A simulation experiment is conducted in this subsection by introducing the value assessment method based on similarity measure with hesitant fuzzy information.

### 4.1 The process to generate the best enterprise

First of all, four chemical enterprises are selected from Hebei Province, Shandong Province, Shanxi Province and Sichuan Province. The decision maker is invited from a shareholder of another chemical enterprise. Then, based on the ten attributes demonstrated in Table 1, the decision maker provides his preference towards these enterprises by using hesitant fuzzy sets. These results are shown in Table 2 and Table 3.

*Table 2: Value assessments of the decision maker*

| *10 | A 1 | A 2 | A3 | A4 | A5 |
|---|---|---|---|---|---|
| 1 | {1, 2} | {2, 4} | {2, 3} | {4, 5} | {7, 8} |
| 2 | {3} | {7, 8} | {2, 3, 5} | {6, 7} | {2, 3, 4} |
| 3 | {8} | {4, 5} | {2, 3} | {4, 5} | {1, 2} |
| 4 | {2, 4} | {1, 3} | {2, 3} | {7} | {5, 6} |

*Table 3: Value assessments of the decision maker*

| *10 | A6 | A7 | A8 | A9 | A10 |
|---|---|---|---|---|---|
| 1 | {4, 5} | {1, 3} | {2, 5} | {7} | {5} |
| 2 | {3, 4, 5} | {6, 7} | {6, 7} | {2, 3} | {2, 4} |
| 3 | {1, 2, 3} | {4, 5} | {4, 5} | {3, 5} | {6, 7} |
| 4 | {2, 3} | {6, 7} | {2, 3} | {7} | {8, 9} |

After that, weighted similarity measure defined in Definition 6 can be introduced to calculated general correlation coefficient in Eq. (6) to obtain the final solution in Figure 1.

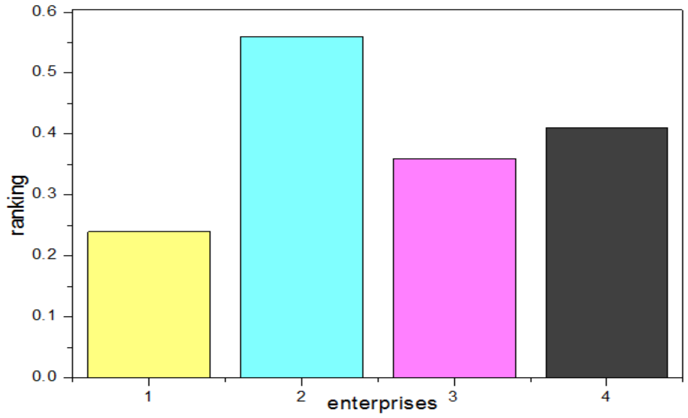


*Figure 1: The ranking order of all enterprises*

### 4.1 Analysis of the simulation experiment

Chemical enterprise is an important aspect of national economy and thus plays significant role for the development of a country. It involved dangerous chemical goods, chemical technology and especially great environmental risk. Due to the special characteristics of petrochemical enterprise, more risk source, serious accident, accident cascading, high uncertainty, difficulty of assessment and complexity. The process of generating chemical productions includes many flammable and explosive, low boiling point, low flash point, poisonous and harmful materials. More importantly, there are several environmental risks from raw material to sales in the process of transportation. These factors may result in the difficulty to evaluate value assessment of a chemical enterprise. The decision maker may feel difficulty to provide evaluations of different chemical enterprises on the basis of the ten attributes. Hesitant fuzzy set is verified to be a useful way to deal with this problem. In the future, more hesitant fuzzy information based method will introduce in evaluating value assessment of a chemical enterprise. The advantages of this proposed method can be summarized as: (1) It can help the decision maker provides value assessment more comprehensively; (2) It can portray uncertain and complex information of chemical industry; (3) It can solve value assessment of chemical enterprises objectively.

## 5. Conclusions

In this paper, we develop a method to evaluate enterprise value which denotes the value that an enterprise can create and has been widely applied venture investment, financing, enterprise annexation and so on. Chemical enterprise as an important aspect of national economy is focused on.In chemical industry, enterprise value is different to other general enterprises. Risk and safety should be highlighted and dangerous chemical goods, chemical technology and especially great environmental risk should be considered. In order to evaluate value of a chemical enterprise objectively and scientifically, we develop a fuzzy decision making method based on hesitant fuzzy information. Based on this hesitant fuzzy model, similarity measure is introduced to aggregate hesitant fuzzy assessments provided by the decision maker and generates a final optimal enterprise whose value is the best one in all evaluated enterprises. The advantages and disadvantages are also analysed in a simulation experiment. In the future, this proposed method may be extended to more chemical enterprises and help them improve their enterprise value to achieve high level of competitiveness.

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