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Supplier Management of Chemical Enterprises Based on Coordination of Multi-tier Suppliers

Qiang Ma

XI'an International University, Xi'an, XI'an 710077, China
maqiang8287@163.com

As the process of economic globalization, the management of supply chain is more and more important. In chemical industry, its characteristics decide that the management of supply chain is different to other industries such as the high requirement for transportation and the relative long supply chain. According to these characteristics, we analyze the existing studies to verify the importance of supplier management from the perspective of the coordination of multi-tier suppliers. In order selection rational multi-tier suppliers, the probability linguistic information is introduced to help the decision maker construct decision matrix and distance measure between two probabilities linguistic terms are defined to aggregate probability linguistic information to generate the final result. Then, the illustrative example is demonstrated by using the proposed probability linguistic information based assessment method.

1. Introduction

In order to keep up with economic integration, the management of supply chain has attracted much attention from all walks of life. Some researchers think that the competitive of supply chain decides the role of the enterprise. In particular, in economic globalization, supply chain and value chain provide new opportunity for the developing country. When copying with the impact of the financial crisis, coordination among suppliers will help enterprises in a common supply chain work together in the spirit of unity (Xiao et al., 2015). Then, after the financial crisis, they will rapidly back to the path of prosperity. Thus, the management of supply chain is more and more important.

In chemical industry, the management of supply chain is different to other industries (Xu et al., 2014; Zhou et al., 2003). In the process of generating chemical product, raw material, semi-finished product and finished product are always corrosive. The requirement for container and tube equipment is relative high. If there is bias in the process of transporting raw material or products, the consequence may be severe. It may result in the loss of many lives and damage to the environment. In addition, the length of supply chain is relative long including the exploration in the upstream, sails in the downstream and especially oil refining and manufacturing in the middle chain. Moreover, the consuming of resource in chemical industry is relative high compared with other industrial such as manufacturing of laptop and entertainment industry. These characteristics decide that the management of supply chain in chemical industry must satisfy some requirements related to safety and industry standard.

Xie et al., (2012) analysed the relationship between supply logistics synchronization, supply chain agility and firm performance to meet the needs of the downstream manufacturers. Li et al., (2016) provided theoretical research on supply chain governance including concept, intention and normative analysis framework and uses the result of this theoretical research to promote and improve the future research in the field of supply chain governance.

Supplier as the core in supply chain should be focused on. Up to now, the review of supplier in supply chain can be divided into two aspects which are assessment of supplier performance and selection of suppliers. No matter which one, there is an important factor that should be paid attention to. That is coordination of multi-tier suppliers. As above mentioned, the length of chemical supply chain is relative long and thus it can be divided into multiple tiers. The management of each tier may be different according to their characteristics. Therefore, in this paper, by considering coordination of multi-tier suppliers, we focus on selection of suppliers.

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Tian et al., (2016) constructed a new model to study the coordination of supply chain network for chemical enterprises by considering the balance of industrial metabolism, the ability of information interaction and the competitiveness power of mutual enterprises. Jiang (2013) focused on green chemical supply chain to assess the degree of chemical supply chain by using fuzzy comprehensive evaluation method and analysed corresponding factors which may influence on green supply chain.

Although the existing research can copy with most problems of selecting suppliers, they cannot deal with all situations such as supplier selection of chemical enterprise in this paper. For suppliers of chemical enterprises including multiple tiers, the selection of suppliers is often complex and uncertain. Thus, it is often difficult for experts or common people to provide their knowledge or experiment for this problem. That is, the experts have limited knowledge and experience to judge different suppliers. As such, we face a challenge which is how to assist expert provide judgments which are suitable their willing.

In order to overcome this problem, many uncertain information expressions have been developed such as fuzzy set, intuitionist fuzzy set, fuzzy linguistic fuzzy set, 2-tuple linguistic fuzzy set, hesitant fuzzy linguistic set and so on. Here, hesitant fuzzy linguistic is considered as a popular way and can handle many uncertainties. Hesitant fuzzy linguistic term set allows experts or common people express their assessments by using several linguistic terms simultaneously. Once the experts think this linguistic term accords with their willing, they can use it. This linguistic term set is more appropriate than classical linguistic term set or 2-tuple linguistic term set for copying with a real case. Gou and Xu (2016) defined some new basic operational laws for hesitant fuzzy linguistic term set to promote its application. Liao et al., (2014) developed new distance and similarity measures to calculate the deviation between two hesitant fuzzy linguistic term sets. However, there is a big problem. In hesitant fuzzy linguistic term set, the probability of each term is considered as same importance. But in real cases, it does not always exist. The probability of each linguistic term is always different. Therefore, probability linguistic term set is developed by Pang et al., (2016) to deal with this problem. In probability linguistic term set, the probability of each linguistic term can be obtained according to their different importance. Merigo (2014) developed new induced operators with probability information to address linguistic group decision analysis. Pang et al., (2016) applied probability linguistic term sets in group decision making and improved the existing studies.

In this paper, according to probability linguistic term set, we develop a new distance measure between two probability linguistic term sets and apply it to aggregate probability linguistic term information of different suppliers. Closeness coefficient in TOPSIS is introduced to rank all alternatives in this problem and an optimal solution is selected. An illustrative example is demonstrated to illustrate the effectiveness of the probability linguistic term based assessment method. The construction of this paper is constructed as follows. Section 2 analyses the problem of selecting a supplier in chemical industry and gives some explanation of supply chain of chemical industry. Section 3 introduces probability linguistic term set and its distance measure, and then uses it to build assessment model. Section 4 demonstrates an illustrative example. Section 5 concludes this paper.

2. The demonstration of supply chain of chemical industry

In Figure 1, the supply chain of chemical industry is demonstrated and multiple tiers of suppliers are described.

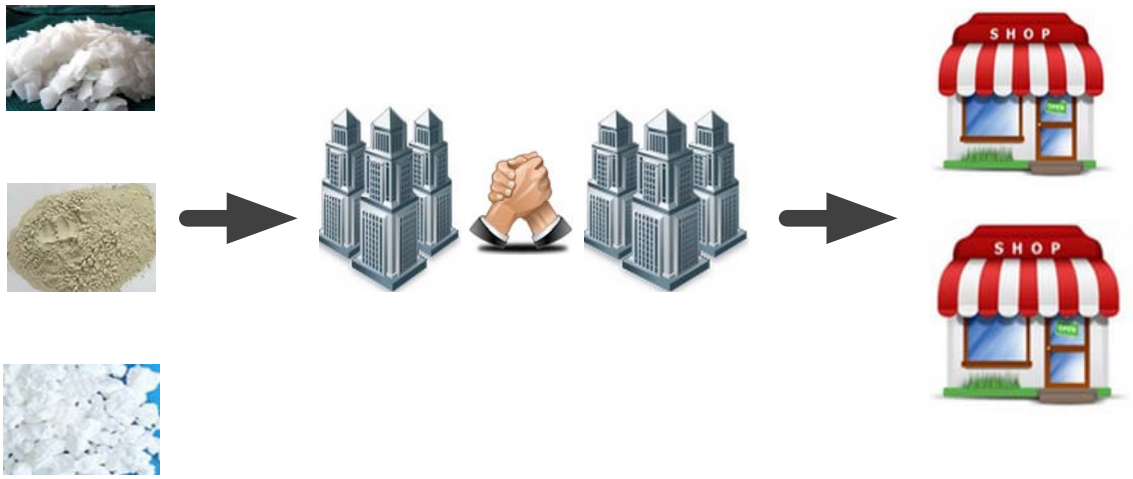

Figure 1: The supply chain of chemical industry

3. Assessment model

Recently, linguistic decision making has attracted much attention from many researchers. It considered as a very useful tool when we want to copy with uncertainty data or hesitant information given by some experts especially collected by non-academic people. These people often have different backgrounds, knowledge, risk preferences or other attitudes towards different assessment alternatives as mentioned in Introduction. In this section, probability linguistic term based assessment model will be constructed and applied in the assessment problem in this paper.

3.1 The concepts of probability linguistic information

Hesitant fuzzy linguistic information is the basis of probability linguistic information. Thus, before introducing probability linguistic term sets, hesitant fuzzy term sets will firstly be introduced in the following.

Definition 1. Suppose F={f_0, f_1, ..., f_g} denotes a linguistic framework including g linguistic terms which are arranged as increasing order. Hesitant fuzzy linguistic term can be defined as

$$HL = \{ fi\ (i = 1, 2, ..., len(fi)) \mid i \in F\} \quad (1)$$

Here, f_i indicates a possible linguistic term selected from the set F and len(f_i) denotes the length of hesitant fuzzy terms here. For example, when a professor assesses two students by using hesitant fuzzy linguistic term, the assessments can be denoted by {f_i = good, f_2 = very good} and {f_2 = very good}.

Then, the basic operations of hesitant fuzzy linguistic term can be provided as follows.

Definition 2. Given three hesitant fuzzy linguistic terms denoted by F_1 = {f_a | a = 1, 2, ..., len(f_a)}, F_2 = {f_b | b = 1, 2, ..., len(f_b)} and F_3 = {f_c | c = 1, 2, ..., len(f_c)}, the operation law can be defined as follows:

(1) $f_1 \oplus f_2 = \bigcup_{f_a \in f_1, f_b \in f_2} f_a \oplus f_b$;

(2) $f_1 \oplus f_2 = f_2 \oplus f_1$;

(3) $(f_1 \oplus f_2) \oplus f_3 = f_1 \oplus (f_2 \oplus f_3)$;

(4) $\lambda(f_1 \oplus f_2) = \lambda f_2 \oplus \lambda f_1$;

(5) $f_1(\lambda_1 \oplus \lambda_2) = \lambda_1 f_1 \oplus \lambda_2 f_1$.

In the above hesitant fuzzy linguistic term, there is an assumption that the probability of each linguistic term is equal. However, in the real case study, this requirement is difficulty to be satisfied. In order to copy with this problem, probability linguistic term will be developed by Pang et al. (2016).

Definition 3. Let F = {f_0, f_1, ..., f_g} be a linguistic term framework including g discrete linguistic terms. The probability hesitant linguistic term set which is called simply called probability linguistic term is defined in the following.

$$PL = \left\{ (f_\alpha, p_\alpha) \middle| f_\alpha \in F, p_\alpha \geq 0, \alpha = 1,2,...,len(f_\alpha), \sum_{\alpha=1}^{len(f_\alpha)} p_\alpha \leq 1 \right\} \quad (2)$$

Here, f_α denotes the possible linguistic term and p_α represents the probability of f_α. Thus, (f_α, p_α) is considered as binary variable. In general, when we use the above probability linguistic term set, only will the known part be applied.

For Definition 3, it should be noted that when $\sum_{\alpha=1}^{len(f_\alpha)} p_\alpha = 1$, it means that there is no complete information and the sum of all probability is equal to 1. Similarly, when $\sum_{\alpha=1}^{len(f_\alpha)} p_\alpha < 1$, it means that there is partial ignorance and incomplete information exists. In a practical case, the decision maker is often difficult to provide exactly linguistic assessments for alternatives especially for a complex assessment problem because of their limited knowledge or experiment. Therefore, incomplete information as mentioned above may appear regularly.

The relationship between probability linguistic term set and classical linguistic term set is demonstrated in Figure 1.

3.2 Distance measure

It is difficulty to directly compare two probability linguistic terms sets. As such, distance measure based method is developed in this section to deal with this problem.

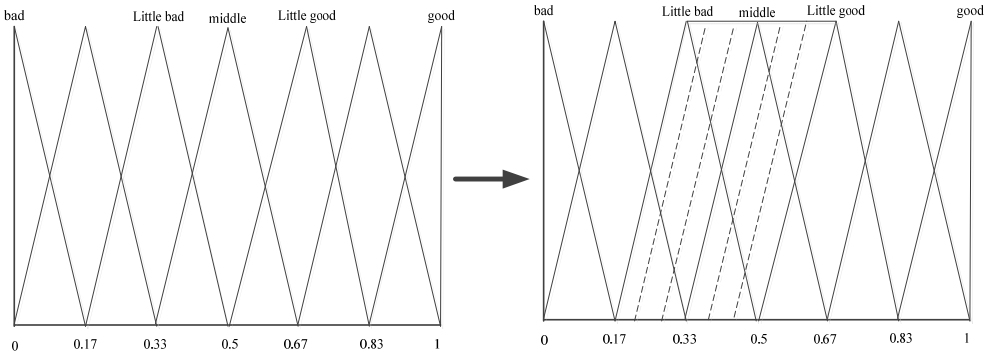

Figure 2: The demonstration of probability linguistic information

Distance measure as a popular way to calculate the deviation between two objectives has been widely applied in decision making environment. Up to now, there are many useful distance measure based method such as TOPSIS, entropy measure, VIKOR and correlation coefficient. Then, we will firstly give the definition of distance measure between two probability linguistic terms.

Definition 4. Given two probability linguistic term PL_1 and PL_2, the basic law of distance measure will be defined in the following.

(1) $0 \le Dis\left(PL_1, PL_2\right) \le 1$;

(2) $Dis\left(PL_1, PL_2\right)=0 \Leftrightarrow PL_1=PL_2$;

(3) $Dis\left(PL_1, PL_2\right)=Dis\left(PL_2, PL_1\right)$;

(4) $Dis\left(PL_1, PL_2\right)+Dis\left(PL_2, PL_3\right) \ge Dis\left(PL_1, PL_3\right)$.

According to Definition 4, the definition of distance measure between two probability linguistic terms is defined as follows.

Definition 5. Given three hesitant fuzzy linguistic terms denoted by $PL_1 = \{(f_a, p_a) \mid a=1, 2, ..., len(f_a)\}$ and $PL_2 = \{(f_b, p_b) \mid b=1, 2, ..., len(f_b)\}$, distance measure between PL_1 and PL_2 is defined as

$$Dis\left(PL_1, PL_2\right)=\left|PL_1\text{-}PL_2\right|=\sum_{b=1}^{len(f_b)}\sum_{a=1}^{len(f_a)}\left(\left|f_a\text{-}f_b\right|, p_a \times p_b\right)=\sum_{b=1}^{len(f_b)}\sum_{a=1}^{len(f_a)} f_{\left(\left|a\times p_a - b\times p_b\right|\right)} \tag{3}$$

Where $Dis(PL_1, PL_2)$ satisfies the law in Definition 4.

Based on Definition 5, two probability linguistic terms can be compared by introducing the maximum value. The distance between the maximum value and the probability linguistic term is smaller, the probability term is regarded as better, which is based on the idea of TOPSIS and VIKOR methods.

3.3 The procedure of the decision making model

In this section, the probability based decision making model will be constructed in order to help researchers use the proposed method.

Step 1. Suppose that an assessment problem includes suppliers denoted by alternatives S_i (i=1, ..., s) and D attributes denoted by D_j (j=1, ..., d). Different attributes have different importance which is determined by the decision maker. They are represented by $w = (w_1, \ldots, w_d)^T$ such that $0 \le w_j \le 1$ (j = 1, ..., d) and $\sum_{i=1}^{d} w_j = 1$.The decision maker provides their assessments about suppliers by using probability linguistic terms to form decision matrix.

$$PL_{s\times d} = \begin{bmatrix} PL_{11} & PL_{12} & \cdots & PL_{1d} \\ PL_{21} & PL_{21} & \cdots & PL_{2d} \\ \vdots & \vdots & \ddots & \vdots \\ PL_{s1} & PL_{s2} & \cdots & PL_{sd} \end{bmatrix} \quad (4)$$

Step 2. The maximum value and the minimum value of possible probability linguistic terms are provided as follows.

$$PL^{+} = \{PL_1^{+}, \ldots, PL_n^{+}\}, \quad (5)$$

$$PL^{-} = \{PL_1^{-}, \ldots, PL_n^{-}\}. \quad (6)$$

Here,

$$PL^{+} = (f_1, 1), \quad (7)$$

$$PL^{-} = (f_{len}, 1). \quad (8)$$

Step 3. By using the distance measure in Definition 5, the aggregated value of each alternative can be obtained.

$$CCi = \frac{dis(PL_{ij}, PL^{-})}{dis(PL_{ij}, PL^{-}) + dis(PL_{ij}, PL^{+})}, \; i = 1, \ldots, s. \quad (9)$$

Step 4. The rank-order of all alternatives can be generated as a solution to the MADM problem.
The mentioned procedure is demonstrated in Figure 3.

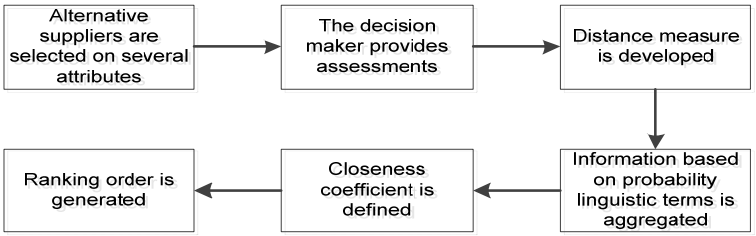

Figure 3: The procedure of the model

4. Simulation experiment

In this section, the illustrative example is demonstrated by using the proposed probability linguistic information based assessment method.
In order to investigate the supplier selection from the perspective of coordination of multi-tier, we invite a manager of a chemical enterprise as the decision make in this paper. The decision maker identifies five attributes demonstrated in Table 1 where the explanations of attributes are also provided to be easily understood. Then, according to these attributes, the decision maker provides assessments of five suppliers in Table 2.

Table 1: Explanation of attributes

	Explanation	Meaning
1	Cost	includes price, material cost and other fees
2	Safety	includes material safety, equipment safety
3	Service	Includes pre-sale service and training
4	Quality	whether it satisfies requirements
5	Delivery	whether it deliver products in time

By using distance measure between two probability linguistic term sets in this paper, the assessments in Table 2 can be aggregated and ranking order can be obtained by using closeness coefficient in TOPSIS. Thus, the ranking order is demonstrated in Table 3. Supplier 3 is selected as the best supplier with the best performance.

Table 2: Assessments of the decision maker

Supplier	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5
1	{(f_1,0.4),(f_2,0.6)}	{(f_2,1)}	{(f_2,0.3),(f_3,0.4)}	{(f_3,1)}	{(f_2,0.2),(f_2,0.8)}
2	{(f_2,1)}	{(f_{13},0.5),(f_4,0.5)}	{(f_3,1)}	{(f_1,1)}	{(f_3,0.4)}
3	{(f_1,0.2),(f_3,0.8)}	{(f_4,1)}	{(f_3,0.4),(f_4,0.6)}	{(f_4,1)}	{(f_3,0.5),(f_4,0.5)}
4	{(f_1,1)}	{(f_2,0.4),(f_3,0.5)}	{(f_2,1)}	{(f_2,0.2),(f_3,0.7)}	{(f_3,1)}

Table 3: Ranking order and result of supplier selection

	Ranking order
Alternative 1	3
Alternative 2	2
Alternative 3	1
Alternative 4	4

5. Conclusions

With the development of economic globalization, supply chain and value chain provide new opportunity for the developing country and thus the management of supply chain is more and more important. In chemical industry, its characteristics decide that the management of supply chain is different to other industries such as the high requirement for transportation and the relative long supply chain. According to these characteristics, we analysed the existing studies to verify the importance of supplier management from the perspective of the coordination of multi-tier suppliers. In order selection rational multi-tier suppliers, the probability linguistic information is introduced to help the decision maker construct decision matrix and distance measure between two probability linguistic terms are defined to aggregate probability linguistic information to generate the final result. Then, the illustrative example is demonstrated by using the proposed probability linguistic information based assessment method.

References

Chen Z.S., Chin K.S., Li Y.L., Yang Y., 2016, Proportional hesitant fuzzy linguistic term set for multiple criteria group decision making, Information Sciences, 37, 61-87. Doi: 10.1016/j.ins.2016.04.006.

Gou X.J., Xu Z.S., 2014, Novel basic operational laws for linguistic terms, hesitant fuzzy linguistic term sets and probability linguistic term sets, Information Sciences, 372, 407-427. Doi: 10.1016/j.ins.2016.08.034.

Lei W.N., Li Y.J., Shi D., 2016, Theoretical research on supply chain governance: Concept, intention and normative analysis framework, Nankai Business Review, 19, 4-15.

Liao H.C., Xu Z.S., Zeng X.J., 2014, Distance and similarity measures for hesitant fuzzy linguistic term sets and their application in multi-criteria decision making, Information Sciences, 271, 125-142. Doi: 10.1016/j.ins.2014.02.125.

Merigo J.M., Casanovas M., Palacios-Marques D., 2014, Linguistic group decision making with induced aggregation operators and probability information, Applied Soft Computing, 24, 669-678.

Pang Q., Wang H., Xu Z., 2016, Probability linguistic term sets in multi-attribute decision making, Information Sciences, 369. 128-143.

Tian D.J., Wei K.C., Xu J.J., Ji X., 2016, The coordination evaluation models of supply chain network for chemical enterprises, Chemical Industry and Engineering Progress, 35(7), 2285-2292.

Xie L., Ma S.H., Gui H.M., Huang P., 2012, The relationship among supply logistics synchronization, supply chain agility, and firm performance, Science Research Management, 33(11), 96-104.

Xu Q., 2014, Assessment of green supply chain in chemical enterprises based on Fuzzy-AHP, Chemical Management, 107-108.

Xiao J.H., Xie K., Wu Y., Liao X., 2015, The supply chain transformation from being partner – oriented to being customer-oriented: a double-case study on the supply chains in ecommerce enterprises, Management World, 4, 137-188.

Zhou Y.Z., Zeng M.G., Cheng S.W., Hua F., Yin Q.H., 2003, Supply chain long range planning and investment decision making system in chemical industry, Journal of Chemical Industrial and Engineering, 54, 659-664.