CHEMICAL ENGINEERING TRANSACTIONS

VOL. 59, 2017

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216

DOI: 10.3303/CET1759185

Research on Location of Hazardous Chemical Logistics Center based on Improved TOPSIS Method

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Hazardous chemical is the chemical product in chemical industry. Hazardous chemicals are often toxic. Some hazardous chemicals are corrosive, or easily lead to explosion. In the process of production, storage and transportation, hazardous chemicals can easily lead to leakage or explosion accidents. These result in a large number of casualties and damage to the surrounding environment. Logistics center is an important part of logistics system. Hazardous chemical logistics center involves many aspects. The superior hazardous chemical logistics center can not only reduce the cost, but also can reduce the loss to the minimum. Therefore, it is very important to choose a reasonable hazardous chemical logistics center. In this paper, we use the improved TOPSIS method to study the location of the hazardous chemical logistics center. By constructing the reasonable evaluation indexes, we carry out the research on location of the hazardous chemical logistics center based on improved TOPSIS method. The experimental results provide the help to decision makers.

1. Introduction

With the rapid development of economy, more and more hazardous chemicals are used. The increasing production of hazardous chemicals has brought great challenges to the survival, storage and transportation of the hazardous chemical supply chain. Once the hazardous chemical in the event of a leak or explosion, it not only causes casualties, but also causes irreversible damage to the environment. Through selecting the location of the hazardous chemical logistics center, we can effectively reduce the risk of hazardous chemicals and reduce the cost and the loss caused by the accident to the lowest.
The numbers of the hazardous chemicals accidents and deaths of 2013-2015 are shown in the following table.

Table 1: The numbers of the hazardous chemicals accidents and deaths of 2013-2015

Years	Accidents	Deaths
2013	143	211
2014	114	166
2015	97	157

At present, many scholars have carried on the research to the chemical transportation and the choice questions (Zhang et al., 2016; Baumann-Stanzer et al., 2016; Mocellin et al., 2016; Houdijk 2016). The geographical distribution of chemical production base had a significant impact on the industrial development and the regional environment sustainably. Common evaluation indicators included the impact of air quality, the impact on the surrounding community, etc. In order to achieve this goal, the decision makers considered the regional air quality, the emissions of the new production site and the local meteorological conditions (Cai t al., 2014). After that, the scholars used Monte Carlo method to optimize the best location of the new chemical production base. The study could not only determine the potential impact of air quality on the geographical distribution of chemical plants, but also selected the chemical bases. Some scholars used the two stage analysis method to plan the hazardous chemical logistics network. The first stage was to define the relationship among logistics center, inventory, transportation and service quality. The second step used the AHP to conduct the warrant analysis between the criterions and get the total assessed value.

Please cite this article as: Jianfeng Luo, Jianlan Guo, 2017, Research on location of hazardous chemical logistics center based on improved topsis method, Chemical Engineering Transactions, 59, 1105-1110 DOI:10.3303/CET1759185

In this paper, in order to reduce the risk of hazardous chemical and protect the safety of life and property of the country and the people, we study on location of the hazardous chemical logistics center. In this paper, we put forward the improved TOPSIS method by using the entropy method and TOPSIS method. After that, we use this method to evaluate the hazardous chemical logistics center and get the evaluation result. The evaluation result provides help for decision makers to make the final decision. The first part of this article is introduction and second part is entropy method. The first part and the second part introduce the research background and the basic algorithm. The third part is the improved TOPSIS method. In the third part, we propose an improved TOPSIS method by combining entropy method with TOPSIS. The fourth part is the experiment. We set up the evaluation index to evaluate the logistics center of hazardous chemical. The fifth part is the conclusion.

2. Entropy method

Entropy method is an objective weighting method. We suppose there are *n* alternative schemes. Each scheme has *m* evaluation indexes. x_{ij} is the *j* evaluation index of *i* alternative scheme.
Information entropy is

$$H(x) = -\sum_{i=1}^{n} p(x_i)\ln p(x_i) \tag{1}$$

The entropy of *j* index is：

$$e_j = -k\sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{2}$$

The entropy method is as follows
a. The original matrix is processed by dimensionless data

$$Y = (y_{ij})_{n\times m} \tag{3}$$

b. Calculate P_{ij}

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{4}$$

c. Calculate the entropy of *j* index：

$$e_j = -k\sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{5}$$

$$e_j = k\ln m \tag{6}$$

Where,

$$k = \frac{1}{\ln m}, \quad 0 \le e_j \le 1$$

d. Calculate the difference coefficient of *j* index：

$$g_j = 1 - e_j, 0 \le g_j \le 1 \tag{7}$$

5 Calculate the weight of *j* index

$$w_j = \frac{g_j}{m - E_e} \tag{8}$$

$$E_e = \sum_{j=1}^{m} e_j \tag{9}$$

Where

$$0 \le w_j \le 1, \sum w_j = 1$$

3. The improved TOPSIS method

Famous scholars Hwang and Yoon proposed TOPSIS in Multiple Attribute Decision Making. The basic principle of TOPSIS method is to obtain the ideal point of each option firstly, then calculate the distance between this point and the optimal solution and the worst solution, finally get the relative closeness and sort each scheme (Walczak et al., 2017; Shi et al., 2016; Luo and Ren, 2016). Among them, the alternatives do not necessarily exist in the best and worst schemes (Sen et al., 2015). At present, TOPSIS method is widely used in chemical Engineering (Akbaş et al., 2017), architecture (Wang et al., 2017), energy (Sindhu et al., 2017), Finance (Adel et al., 2017) and so on.

In this paper, we propose an improved TOPSIS method by combining the improved entropy method with TOPSIS. First, we use the improved entropy method to get the weights of each index, and then use the TOPSIS method to rank the schemes.

The improved entropy method is as follows.

Step 1. The different coefficients of each index are calculated according to the steps of entropy weighting.

Step 2. Seek the biggest difference coefficient ratio.

$$D = \frac{\max g_i}{\min g_j}(j \subset N) \tag{10}$$

Step 3. Calculate the mapping ratio of 1-9 scale.

$$R = \sqrt[\alpha-1]{\frac{D}{\alpha}} \tag{11}$$

In the formula, α is the adjustment coefficient which represents the maximum scale value in the improved entropy method.

If $D \le 9$, α takes the integer which is closest to D, or α=9.

Step 4. Calculate the mapping value of 1-9 scale.

Step 5. Calculate the otherness coefficients of any two indexes.

$$r_{jk} = g_j / g_k \tag{12}$$

If $r < 1$

$$r_{jk} = g_k / g_j \tag{13}$$

If r_{jk} is close to $4\times R^3$, The relative importance of index *j* and index *k* is 4. The Relative importance of index *j* and index *k* is 1/4.

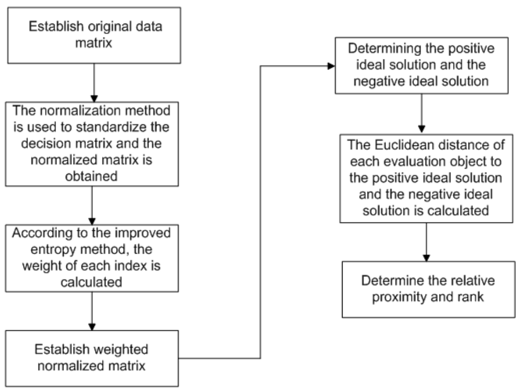

Figure 1: steps of the improved TOPSIS method

Therefore, the steps of the improved TOPSIS method are shown in figure 1.
Specific steps are as follows.
(1) Get the Initial matrix according to the specific index value.

$$(M_{ij}) = \begin{pmatrix} M_{11} & M_{21} & \cdots & M_{m1} \\ M_{12} & M_{22} & \cdots & M_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ M_{1n} & M_{2n} & \cdots & M_{mn} \end{pmatrix} \tag{14}$$

(2) Standardize the decision matrix and get the normalized matrix.

$$(P_{ij})_{mn} = \begin{pmatrix} P_{11} & P_{21} & \cdots & P_{m1} \\ P_{12} & P_{22} & \cdots & P_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ P_{1n} & P_{2n} & \cdots & P_{mn} \end{pmatrix} \tag{15}$$

Where

$$P_{ij} = \frac{M_{ij}}{\sum_{i=1}^{m} M_{ij}} \tag{16}$$

(3) The weights of each index are calculated according to the improved entropy method.
(4) Construct the weighted normalized matrix.

$$V = (v_{ij})_{mn} = \begin{pmatrix} w_1 P_{11} & w_1 P_{21} & \cdots & w_1 P_{m1} \\ w_2 P_{12} & w_2 P_{22} & \cdots & w_2 P_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ w_n P_{1n} & w_n P_{2n} & \cdots & w_n P_{mn} \end{pmatrix} \tag{17}$$

(5) Determine the positive ideal solutions and negative ideal solutions of each index.

$$V^{+} = \left\{ (\max_{1 \le j \le m} v_{ij} \,|\, j \in J_1), (\min_{1 \le j \le m} v_{ij} \,|\, j \in J_2) \right\} \tag{18}$$

$$V^{-} = \left\{ (\min_{1 \le j \le m} v_{ij} \,|\, j \in J_1), (\max_{1 \le j \le m} v_{ij} \,|\, j \in J_2) \right\} \tag{19}$$

J_1 is benefit index and J_2 is cost index
(6) Calculate the Euclidean distances of each evaluation object to the positive ideal solution and the negative ideal solution.

$$d_i^{+} = [\sum_{j=1}^{n} (v_{ij} - v_j^{+})^2]^{\frac{1}{2}} \tag{20}$$

$$d_i^{-} = [\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2]^{\frac{1}{2}} \tag{21}$$

(7) Determinate the relative closeness.

$$C_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \tag{22}$$

According to the relative closeness, the evaluation objects are sorted.

4. Experiment

In order to study the location of the hazardous chemical logistics center, we firstly establish the index system. Specific indexes system and weights are shown in the following table.

Table 2: Indicators for analysis

Target layer	Criterion layer	Weights	Base layer	Weights
Location of the hazardous chemical logistics center	Geographical environment	0.26	geological conditions	0.4
			hydrologic condition	0.4
			Available area and capacity	0.2
	Environmental protection	0.23	Waste disposal capacity	0.363
			Impact on the surrounding environment	0.342
			safe distance	0.295
	Social policies	0.13	Regional industrial structure	0.268
			Government support	0.486
			Local people attitude	0.246
	Facilities	0.15	Public facilities	0.177
			Traffic conditions	0.218
			Hazardous chemical processing equipment	0.281
			Hazardous chemicals storage and transportation Equipment	0.324
	Related costs	0.10	land cost	0.460
			Construction cost	0.313
			Operating cost	0.227
	Correlation coefficient	0.13	Fixed risk factor	0.5
			Variable risk factor	0.5

After that, we evaluate the four hazardous chemicals logistics centers and the results are shown as table 3.
d_1^+=0.1328, d_1^{+-}=0.1128, d_2^+=0.0934, d_2^{+-}=0.1205, d_3^+=0.0875, d_3^{+-}=0.1067, d_4^+=0.0894, d_4^{+-}=0.1143

Table 3: Indicators for analysis

Logistics Center	C^i	Ranking
A	0.4592	4
B	0.5633	1
C	0.5494	3
D	0.5611	2

5. Conclusion

The location of the hazardous chemical logistics center is related to the property and safety of the country and the people. Hazardous chemicals are potentially hazardous to human health and the environment due to their dangerous and explosive properties. In this paper, in order to make a better research on the location of the hazardous chemical logistics center, we propose an improved TOPSIS method and set up the index evaluation system. In the experimental part of this paper, the proposed method is used to evaluate the location of the hazardous chemical logistics center and the evaluation results are helpful for the decision makers. The main contents of this paper include (1) introducing the research background and basic algorithm (2) proposing the improved TOPSIS method (3) establishing the evaluation index and using the improved TOPSIS method to evaluate the location. The results are accurate and effective.

Acknowledgments

Talent Cultivation Program for Outstanding Young Teachers of Guangdong Province in 2014 (2015S02), Special Funds for Demonstration Projects of Dongguan Polytechnic College (Grant No: zheng201708), Dongguan social science and technology development project (201450715600678).

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