CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762229

Research on Emergency Management Capability Evaluation of Hazardous Chemical Supply Chain

Lele Wang

Xi'an International University, Xi'an 710077, China
yuapple2003@163.com

Abstract: Hazardous chemical are different from ordinary commodities. Hazardous chemical has special requirements for production, transportation, storage and other links, such as higher security, more convenient etc. Therefore, the supply chain of hazardous chemical is also different from other commodities. Because hazardous chemical are prone to sudden accidents and serious consequences, the emergency response capability of hazardous chemical supply chain is very important. In this paper, we evaluate the emergency response capability of hazardous chemical supply chain. The establishment of evaluation index can play a guiding role in the foundation of emergency capability of hazardous chemical supply chain. The assessment results can find the deficiency of hazardous chemical supply chain. Enterprises and governments can make up for the shortcomings as soon as possible according to the assessment results. In this paper, the improved GA-AHP method is used to evaluate the results and the results are helpful for decision makers.

1. Introduction

The appearance of chemical has brought more convenience to people's life. Chemical has brought about many new materials, which have enriched people's choices and improved their quality of life. With the rapid development of the national economy, the demand for chemical products in China is increasing day by day. These have accelerated the rapid growth of the chemical industry. At the same time, hazardous chemical poses a potential danger to our lives (Tarun and Rand, 2017; Wang, 2017; Ju, 2017; Luo and Guo, 2017).

It the hazardous chemical causes the accident in the process of production, storage, use and transportation. It is easy to cause a large number of casualties, property losses and environment pollution (Fyffe et al., 2016). If the chain reaction happens again and the Domino effect is formed, the consequences will be more disastrous. In August 12, 2015, an explosion occurred in Tianjin Binhai New Area of China, resulting in 165 deaths, 8 missing, 798 injured and the direct economic losses amounted to 6 billion 800 million yuan. The reason of the accident is the burning of hazardous chemical during storage, causing an explosion of chemicals around them. After the accident of hazardous chemical supply chain, effective emergency treatment can be carried out to minimize the loss caused by the accident (Hanna and Chang, 2017).

Whether the emergency management of hazardous chemical supply chain for enterprises or urban, there are a large number of researchers and research results. At the same time, many scholars believe that the construction of an emergency response system and emergency resources is an indispensable part of emergency management. Chemical safety management started relatively late in China. Since the State Council promulgated the regulations on the safety control of chemical dangerous goods in 1987, it has formed a complete system after more than ten years of development (Jahre et al., 2017).

Generally speaking, the risk prevention of hazardous chemical supply chain is divided into three aspects. The first is strict implementation of the laws and regulations and standards. The second is to build a professional management and service system. The third is the use of the advanced technical support. These three aspects can greatly reduce the risk of accidents in the supply chain of hazardous chemical. However, in real life, due to the various reasons, there are many enterprises and government agencies cannot fully meet the requirements of all aspects. This poses a potential hazard to the hazardous chemical supply chain. Once the accident occurs, in order to minimize the loss of the accident, various aspects should start the emergency management procedures of hazardous chemical supply chain (Toivo et al., 2014).

Please cite this article as: Lele Wang, 2017, Research on emergency management capability evaluation of hazardous chemical supply chain, Chemical Engineering Transactions, 62, 1369-1374 DOI:10.3303/CET1762229

To assess the emergency management capability of hazardous chemical supply chain, we can test the emergency management of hazardous chemical supply chain, find the shortcomings and improve the ability of emergency management with the guidance of the inspection standards. In this paper, we introduce the sudden accident and emergency management of dangerous chemical. After that, we propose an improved GA-AHP algorithm. The main structure of this paper is as follows. The first part introduces the research background of this paper. The second part introduces the sudden accident and emergency management of hazardous chemical. The third part introduces the genetic algorithm. In the fourth part, an improved GA-AHP algorithm is proposed. The fifth part is the experiment and the last part is the conclusion.

2. Sudden accident and emergency management of dangerous chemical

In real life, sudden accident of hazardous chemical occurs suddenly. The reasons are complex. The range is wide. The harm is serious. And the negative influence is great. Generally speaking, the sudden accident of hazardous chemical has the following characteristics.

The first is the unpredictable. Unexpected accident of hazardous chemical is not only unpredictable in time, but also impossible to predict the locations. And the development of tenses is also difficult to control.

The second is the serious losses. Hazardous chemical accident has the strong destructiveness. Hazardous chemical accident is often accompanied by casualties and property losses. Sudden accident of hazardous chemical will cause the political, economic and spiritual losses to the country and people.

The third is the complexity. There are three aspects of the complexity of hazardous chemical accident. Firstly, the cause of the accident is complicated. Hazardous chemical accidents are often caused by many factors. Secondly, the evolution of accident is complicated. Evolutionary mechanism and evolutionary trajectory cannot be predicted. Thirdly, the handling of the accident is complex. Because the factors that cause the accident are various, the treatment of the accident is also very complicated.

The fourth is the urgency. Hazardous chemical accidents are sudden and it is very urgent to deal with.

The fifth is the persistence. In the narrow sense, once the hazardous chemical accident occurs, it is more complicated to deal with and the duration of the accident is longer. In the broad sense, hazardous chemical accident begins with chemicals coming into people's lives and has been accompanied by the continuous use of chemicals.

Emergency management of hazardous chemical is an important part of the chemical supply chain management system. Due to the particularity of hazardous chemical accident, hazardous chemical accident has posed a serious challenge to the emergency management of the entire chemical supply chain. How to respond quickly and accurately in the face of emergencies and coordinate various resources to deal with is related to the effective operation of the entire chemical supply chain. In dealing with hazardous chemical emergencies, we make all kinds of reactions. At the same time, it is necessary to adjust the emergency plan in time to reduce the loss caused by the accident (Vuor et al., 2017).

Hazardous chemical is very destructive and can spread rapidly to other places in a very short period of time. Therefore, taking appropriate measures against hazardous chemical emergencies can prevent the deterioration of the situation in time. Emergency management of hazardous chemical emergency must be timely and effective. At the same time, the emergency management of hazardous chemical will involve many organizations and the emergency plan is also complex. Emergency management of hazardous chemical accident also needs to integrate different resources, coordinate various institutions and ensures the smooth flow of emergency channels.

3. Genetic algorithm

The basic operations in genetic algorithms include replication, crossover and mutation. The principle of replication is that the algorithm selects the excellent individuals according to the fitness function to participate in the next step. Crossover is the operation of two random individuals from the father, resulting in a new constitution. The principle of mutation is to simulate gene mutation, so that, the individuals produce random changes.

The steps of the genetic algorithm are as follows.

The first step is coding.

The second step is the population initialization.

According to the encoding form, the initial population is generated.

$$pop_i(t), t = 1, 2, \cdots, N \tag{1}$$

The third step is to calculate the fitness.

Fitness is used to select individuals for crossover, mutation and other operations.

$$f_i = fitness(pop_i(t)) \tag{2}$$

The fourth step is to select the operator.
The selection probability is,

$$P_i = \frac{f_i}{\sum_i^N f_i}, i = 1, 2, \cdots, N \tag{3}$$

According to the selection operator, the current population chooses individuals to inherit into the next generation.

$$newpop(t+1) = \{pop_j(t),\ j = 1, 2, \cdots, N\} \tag{4}$$

The fifth step is the crossover operator.
Crossover operator is for genetic information exchange among different individuals. A new population is obtained by the crossover operator.

$$crosspop(t+1) \tag{5}$$

The sixth step is the mutation operator.

The purpose of mutation operator is to enhance the diversity of individuals in the colony and form a new group $mutpop(t+1)$. (6)

The seventh step is to decode.
We convert the design values represented by binary numbers to real values.
The flow chart of the genetic algorithm is as follows.

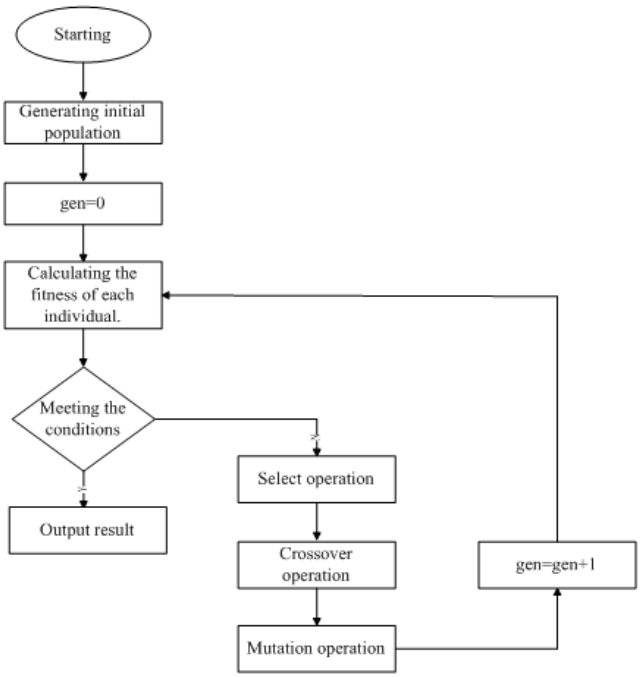

Figure 1: The flow chart of the genetic algorithm

4. Improved GA-AHP algorithm

In the genetic algorithm, individual fitness is the driving force of the evolutionary operation of the algorithm and also the standard to evaluate the individual superiority in the population. In the calculation of individual fitness, we must first decode operation on the binary chromosome encoding. Then, we calculate the individual corresponding objective function value. Finally, according to the type of the objective function, we transform the objective function value into individual fitness according to certain rules.

In the GA-AHP algorithm, the element W_i is the weight of the index B_i. If the elements b_{ij} of the judgment matrix meet $b_{ij}=W_i/W_j$, the judgment matrix is consistent. Therefore,

$$\sum_{j=1}^{n} b_{ij} W_j = \sum_{j=1}^{n} \frac{W_i}{W} \cdot W_j = nW_i \tag{7}$$

$$\sum_{i=1}^{n} \left| \sum_{j=1}^{n} (b_{ij} W_j) - nW_i \right| = 0 \tag{8}$$

In order to solve the judgment matrix, we can obtain the objective function.

$$\min f_{CI}(n) = \frac{\sum_{i=1}^{n} \left| \sum_{j=1}^{n} (b_{ij} W_j) - nW_i \right|}{n} \tag{9}$$

Fitness function can be defined as follows.

$$F(n) = \begin{cases} C_{\max} - f_{CI}(n), C_{\max} > f(n) \\ 0, C_{\max} \le f(n) \end{cases} \tag{10}$$

Where, C_{max} is the maximum estimated value of the objective function $f_{CI}(n)$.

For the genetic algorithm, there are two aspects of crossover probability and mutation probability.

Firstly, when the fitness value of individuals is less than the average fitness value, the crossover probability and the mutation probability are all fixed values. However, when the fitness of individuals is less than the fitness of evaluation, this phenomenon easily leads to the algorithm to fall into the local optimum solution.

Secondly, the cross probability and fitness function are linear, and the mutation probability is also. At this point, if the minimum crossover probability and the minimum mutation probability are small, and the average fitness value is close to the maximum fitness value, most of the individual crossover probability and mutation probability are smaller. If the minimum crossover probability and the minimum mutation probability are larger, the latter will lead to a large number of damage to the good individuals, which is beneficial to improve the efficiency of the algorithm.

We improve the cross probability and mutation probability. Then, we propose the following improved cross probability and mutation probability.

$$P_c = \begin{cases} P_{c3} + (P_{c2} - P_{c3}) \cdot e^{\frac{10 \cdot (f_{avg} - f')}{f_{\max} - f_{avg}}}, f' \ge f_{avg} \\ P_{c2} + \dfrac{(P_{c1} - P_{c2})(f' - f_{avg})}{f_{avg} - f_{\min}}, f' < f_{avg} \end{cases} \tag{11}$$

$$P_m = \begin{cases} P_{m3} + (P_{m2} - P_{m3}) \cdot e^{\frac{10 \cdot (f_{avg} - f)}{f_{\max} - f_{avg}}}, f \ge f_{avg} \\ P_{m2} + \dfrac{(P_{m1} - P_{m2})(f - f_{avg})}{f_{avg} - f_{\min}}, f < f_{avg} \end{cases} \tag{12}$$

Where, f_{max} is the maximum fitness value. f_{avg} is the average fitness value. f_{min} is the minimum fitness value. f' is the larger fitness values between the two crossed individuals. f is the fitness value of variation individuals. The value of P_{c1}, P_{c2}, P_{c3}, P_{m1}, P_{m2} and P_{m3} is (0, 1). At the same time, $P_{c1}>P_{c2}>P_{c3}$ and $P_{m1}>P_{m2}>P_{m3}$.

In the formula X, the three variables of f_{max}, f_{avg} and f_{min} is to measure the degree of concentration of population fitness and describe the relation between p_c, p_m and f_{max}, f_{avg}, f_{min}. In addition, the relation of them is linear. The crossover probability and the variation probability of fitness value close to the maximum fitness f_{max} tend to be stable.

The crossover probability and mutation probability of individuals with maximum fitness in the population are not zero. And it overcomes the shortcomings of linear adaptive operators. The rates of crossover and mutation vary slowly at f_{avg}.

5. Experiment

The assessment of emergency management capability of hazardous chemical supply chain is a comprehensive evaluation of the level and capability of the chemical supply chain in dealing with the sudden hazardous chemical accident. The purpose of the assessment is to find out the deficiencies of the emergency management capability of hazardous chemical supply chain and strengthen the construction of emergency response capability. Therefore, we must establish a reasonable and scientific indicator system and reasonably reflect the emergency response capability of the chemical supply chain. The establishment of indicators must follow the following principles.

The first principle is the scientific. The selection of emergency capability evaluation index of hazardous chemical supply chain should be based on a scientific basis. Only in this way can we get the right evaluation indicators.

The second principle is the purpose. In establishing indicators, we should aim at assessing the emergency management capabilities of the chemical supply chain. Therefore, we must keep in mind the original intention in order to obtain the evaluation results which can help optimize and strengthen the emergency response capability.

The third principle is the combination between the objective index and supervisor index. The objective index and subjective index are combined to ensure the fairness and authority of the evaluation results.

Table 1: The indexes and the weights of the emergency management ability of hazardous chemical supply chain

First level index	Second level index	Weight	Third level index	Weight
Emergency management ability of hazardous chemical supply chain	Warning ability of hazardous chemical accident	0.26	Preparation of emergency plans for hazardous chemical accident	0.27
			Training and drilling of hazardous chemical accident	0.31
			Laws and regulations	0.18
			Hazardous chemical accident detection and early warning	0.24
	Hazardous chemical accident response and handling capacity	0.37	Preparation of emergency materials	0.09
			Enterprise self-help ability	0.11
			Government emergency rescue	0.12
			NGO participation	0.07
			Quick response	0.13
			Hazardous chemical accident report	0.06
			Public opinion management	0.06
			Decision making ability	0.15
			Hazardous chemical accident analysis	0.08
			Information guarantee	0.04
			Logistic service	0.09
	Recovery and reconstruction capability of hazardous chemical accident	0.22	Financial support	0.21
			Amendment of emergency plan for hazardous chemical accident	0.16
			Accident investigation of hazardous chemical	0.23
			Post disaster reconstruction	0.26
			Information release of hazardous chemical accident	0.14
	Informatization and technical ability	0.15	Construction of emergency information platform	0.15
			Video monitoring system	0.18
			Emergency duty system	0.14
			Emergency decision system	0.16
			Emergency dispatching system	0.12
			Emergency treatment technology	0.14
			Logistics technology	0.11

We use fuzzy evaluation method to calculate the score. The index set is *V*={*excellent*, *good*, *normal*, *poor*, *very poor*}. The corresponding score is *V*={1, 0.8, 0.6, 0.4, 0.2}. Because of the length of the space, we only show the final results.

$$S = w'' \cdot B_{ij} = (0.26, 0.37, 0.22, 0.15) \cdot \begin{bmatrix} 0.1862 & 0.7481 & 0 & 0 & 0 \\ 0.1147 & 0.8346 & 0 & 0 & 0 \\ 0.1534 & 0.7850 & 0.158 & 0 & 0 \\ 0.1328 & 0.6213 & 0.247 & 0.031 & 0 \end{bmatrix}$$

$$= (0.1445, 0.7692, 0.0718, 0.0046, 0)$$

$$E = S \cdot V = [0.1445, 0.7692, 0.0718, 0.0046, 0] \cdot (90, 80, 70, 60, 50)^T$$

$$= 79.843$$

Therefore, the assessment result of the emergency management capability of the hazardous chemical supply chain is 79.843.

6. Conclusions

Emergency management of hazardous chemical supply chain can effectively deal with chemical emergencies and take measures to minimize the losses caused by accidents. Assessment of the emergency management capability of hazardous chemical supply chain can help managers discover vulnerabilities in emergency management, prevent and control potential chemical accidents. In this paper, based on the evaluation index, the improved genetic algorithm is used to evaluate the emergency management of hazardous chemical supply chain. The main work of this paper includes. Firstly, we introduce the emergency management and emergency management of hazardous chemical. Secondly, we propose the improved GA-AHP method. Then, we establish the evaluation index of emergency management capability of hazardous chemical supply chain. Finally, we make the assessment of emergency management capability of hazardous chemical supply chain.

Reference

Fyffe L., Krahn S., Clarke J., Kosson D., Hutton J., 2016, A preliminary analysis of Key Issues in chemical industry accident reports, Safety Science, 82, 368-373.

Hanna S., Chang J., 2017, Dependence of maximum concentration from chemical accidents on release duration, Atmospheric Environment, 148, 1-7.

Jahre M., Kembro J., Rezvanian T., Ergun O., Berling P., 2016, Integrating supply chains for emergencies and ongoing operations in UNHCR, Journal of Operations Management, 45, 57-72.

Ju H.L., 2017, Research on the risk assessment of hazardous chemical supply chain and the application, Chemical Engineering Transactions, 59, 1123-1128, DOI: 10.3303/CET1759188

Luo J.F., Guo J.L., 2017, Research on location of hazardous chemical logistics center based on improved topsis method, Chemical Engineering Transactions, 59, 1105-1110, DOI: 10.3303/CET1759185

Tarun M.K., Rand M.M., 2017, Leveraging Chemotype-Specific Resistance for Drug Target Identification and Chemical Biology, Trends in Pharmacological Sciences, In press, corrected proof, Available online 13 October.

Toivo N,, Kyösti L,, Maria L.H,, 2014, Results of the Finnish national survey investigating safety management, collaboration and work environment in the chemical industry, Safety Science, 70, 233-245.

Vuori A., Stoop J., Johnson C., 2017, The need to establish consistent international safety investigation guidelines for the chemical industries, Safety Science, 95, 62-74.

Wang K., 2017, The simulation system of hazardous chemical gas diffusion in plant based on cellular automata, Chemical Engineering Transactions, 59, 661-666, DOI: 10.3303/CET1759111