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Risk Evaluation of Terrorist Attacks against Important Chemical Industries in Urban Areas

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***Abstract*—While terrorism is getting increasingly rampant all over the world, it is significant to identify risk and clarify possible damage mechanism for chemical industries. Aside from the national evaluation method of major danger source, we also consider judging the content of threatening against terrorists attack, and building vulnerability and safety risk in the industry. We will discuss the possible risk of major chemical companies from two aspects: the inherent attraction of the target and target selection of terrorist attacks. Thereafter we use WBS-RBS method to identify the risk of terrorist attacks in petrochemical areas. This thesis lays a theoretical foundation for the risk assessment and control of terrorist attack in important chemical industries.**

Keywords—terrorism sabotage; risk classification; risk analysis; chemical industries

I. INTRODUCTION

Since the new millennium, the Chinese economy has been developing rapidly with a significant increase in the production and use of dangerous chemicals. A report in 2010 shows that China has more than 22,000 dangerous chemical industries which produce more than 7,700 kinds of dangerous chemicals. Although the safety production situation is gradually improved, major accidents still happen from time to time, the fire and explosion accident of Ruihai co. in Tianjing being a typical one. Till August the 18th, 2015, 114 people died, 65 remained out of contact and 674 were hurt in the accident. Moreover, the economic damage is more than 1 billion yuan. Apparently, a study on the safety situation of petrochemical industries is in urgent need.

Nowadays large-scale essential petrochemical industries play an important role in the Chinese economy and social development. Therefore, their losses would eventually reflect on the negative effects of the Chinese economy. These industries generally have following three characteristics: first, their target exposure sign is significant, generally large and easy to be identified and found; second, they have more production links, significant safety risk, low protective hardness of key parts, and high vulnerability; third, because of their chemical nature, they have a large number of dangerous chemicals, which could easily lead to secondary disasters and create extensive damage. Therefore, the consequences of terrorist attacks on these objects are extremely serious. By analyzing the level of loss in unintentional accidents, we make it clear that the consequences of intentional terrorist attacks could be much more severe, which makes a study on the risk of terrorist attacks on petrochemical industries necessary. Therefore, the identification of the risk of terrorist attacks on important chemical economic targets is the premise of analyzing the possible risk and consequences, and also provides the corresponding theoretical basis for constructing the index system and risk evaluation model of terrorist attacks on such objects.

Hazard identification on petrochemical industries and economic targets is widely studied. Li Dongmei, Gao Qingjing and Ge Changrong use the method of major hazard sources identification, while Wei Keji and other researchers use the analysis method of accident tree and system security [5]. However these methods only focus on the internal characteristics of hazard identification, and they do not study the external characteristics of getting attacked or their identification methods. So this article intend to set an example for the research of the judging content of threatening against terrorists attack, building vulnerability at home and abroad, screening and analyzing the possible terrorists attack risk and hazard type on major chemical industries, identifying the assaulted risk of the major chemical industries concentrated district based on the WBS-RBS method, and analyzing and studying with the example of some large national chemical industries cluster in Nanjing.

II. IDENTIFICATION STANDARDS FOR IMPORTANT CHEMICAL INDUSTRIES RISK OF TERRORIST ATTACKS

From the global scope, after the event of 9.11, America started paying attention to the problem of terrorist attacks, reaching a lot of research achievements in policy making and multi-aspect precaution. Their research of the terrorist attacks provides a reference to this paper's research about terrorist attacks on major chemical industries.

On the other hand, China set an evaluation methodology of major hazard source aiming at the chemical accident, on this basis, some improvement being made considering human factors. Although petrochemical industries are different from chemical facilities, they still have the chemical nature, so the evaluation methodology of major hazard source can also guide our study to some extent.

A. Risk Evaluation and Classification Abroad

1) Risk evaluation method of American building vulnerability[6]

Federal Emergency Management Agency (FEMA), Department of Justice (DOJ), and some other government

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agencies responsible for the risk assessment and consequence management analyzed the risk of building vulnerability with the method of seven-factor-analysis. The research studies from seven aspects including the visibility grade, asset value, the target`s values for terrorists, the possibility of terrorists closing target, site population capacity, the availability of hazardous materials and potential collateral damage, which divides the possible risks of building into objective risks and subjective risks. Objective risks are mainly caused by indirect factors including asset value, site population capacity, the availability of hazardous materials and potential collateral damage. Subjective risks are mainly caused by subjective judgment including the visibility grade, the target's value for terrorists, and terrorist accessibility of the target.

2) Industrial department's risk classification method of the USA

Based on the field risk assessment, the U.S. Department of Justice (DOJ) divides industrial department into four levels from the following four aspects: the number of staff workers, the occupation area, the attributes of the industrial departments and the degree of accessibility. Among all the subjective risk they only consider the degree of accessibility. In view of the classification, the American government agencies only consider the protection of object and industrial departments' own risk. So the DOJ focuses more on objective risk other than the terrorists` subjective judgment.

3) Vulnerability evaluation and risk analysis method

The U.S. Application Research Association studied the attacked risk of potential target with the theory of vulnerability evaluation and risk analysis. They judge the vulnerability of potential target from two disciplines including the facilities` vulnerability and the degrees of loss, and classify from the impersonal factor including the degree of protection, the degrees of disaster damage, the injuries and deaths and the loss of properties, but they also fail to consider the terrorists' subjective judgment.

B. The Evaluation Method of Chinese Risk Resources

The assessment of China's hazard sources analyses from the intrinsic risk and reality risk on chemical and other accidents. The intrinsic risk includes the internal characteristics, the process of producing dangerous chemicals and the internal and external situations of the production units. The reality risk considers the risk deduction brought by the prevention measures on the basis of the intrinsic risk.

Based on the above methods, we bring the accidents caused by human activities into the architecture. We intend to describe the probability of the risk evaluation with susceptibility, combining both objective and subjective risk factors to improve the architecture of the assessment of risk resources. The improved indexes of the hazard resource are listed on Table I, Table II and Table III.

TABLE I. INHERENT OF THE IMPROVED INDEXES OF LARGE HAZARD RESOURCES OF REAL RISK

Inherent risk			
Accident susceptibility		***Severity of accident***	
susceptibility of dangerous material accident	Susceptibility of process accident	The accident intensity	Environmental factors at the scene of the accident

TABLE II. RISK MITIGATION FACTOR OF THE IMPROVED INDEXES OF LARGE HAZARD RESOURCES ON TERROR ATTACK

Risk mitigation factor	
Physical protection facilities	Safety management

TABLE III. REAL RISK ON TERROR ATTACK OF THE IMPROVED INDEXES OF LARGE HAZARD RESOURCES ON TERROR ATTACK

Risk of Terror Attack					
Severity of loss		***Susceptibility to attack***			
Casualties	Property damage	Recognition	Accessibility	Symbolism and sensationalism	Intrinsic risk

III. TERRORIST ATTACK RISK EVALUATION OF IMPORTANT CHEMICAL CLUSTER

We use the WRS-RBS method to identify the risk of important chemical and economic target. Based upon analysis of the relation between risk and risk event, we construct the Work Break-down Structure and Risk Break-down Structure, thereby forming WBS-RBS matrix to estimate the risk degree and transform condition one by one.

A. WBS-RBS Method

The WBS method is a bridge between project management and computer science. It means Work Break-down Structure, and the individual cell in the Work Structure is a Work Package. RBS means Risk Break-down Structure. Comprehensive combine the Work Break-down Structure and Risk Break-down Structure to construct WBS-RBS matrix to analyse the possible risk and their degrees. In order to apply the WBS-RBS method to the terrorist attacks Risk Identification of major chemical and economic target in the chemical area, two problems need to be solved. The first is to estimate whether the risk exists, and the second is to estimate the condition of the risk factor turning into the risk event and accident.

Procedure of using WBS-RBS method to identify the risk is as follows:

Confirm the object of risk identification. Confirm the object and range of the risk identification according to the demand before the risk Identification.

Work Break-down, build the Main Part Break-down Structure.

Risk Break-down constructs the Work Break-down Structure. Based on condition of risk, predict the possible risk, and analyze the risk layer-by-layer until all kinds of risks' attribute come to the similarity.

Construct risk Identification matrix. Make the Work Package of Work Break-down Structure in the bottom levels as the line of the matrix. Make the bottom levels' risk of Risk Break-down Structure as the row of the matrix, to build the risk identification matrix.

Estimate whether the risk exists and the condition of the risk translation. Based on the element of the risk Identification matrix, evaluate the possibility of the existence of the "I" Work Package's number "j" risk, if the risk exists, reach "1", if not or have the less risk, reach "0".

The above steps are described in Fig. 1 and Fig. 2. From Fig.1 and Fig. 2, we can deduce the risk matrix.

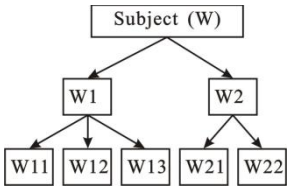

Fig. 1. Main part of Break-down Structure

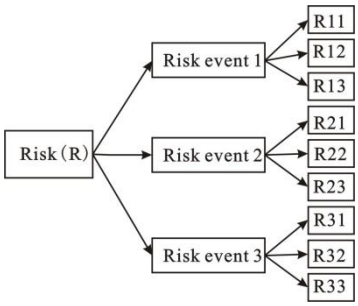

Fig. 2. Risk of Break-down structure

B. Design of Risk Identification Matrix

Terrorist attack of important chemical industries may cause fire disasters, explosions and poison leakage. Considering the influence secondary disasters cause, identifying the areas` risk in major different petrochemical industries after the terrorist attacks in chemical areas, we should mainly research the different type of secondary disaster costs the different influence to the circumstance and other major petrochemical industries in the chemical area after the terrorist attacks.

1) Risk subject Break-down

In the chemical area, all of different chemical industries have possibilities of being attacked. Suppose a chemical area has four important chemical industries a, b, c and d, so there are four risk subject items in this chemical area: petrochemical industry a, b, c and d. These can constitute Risk subject break-down structure as shown in Fig. 3.

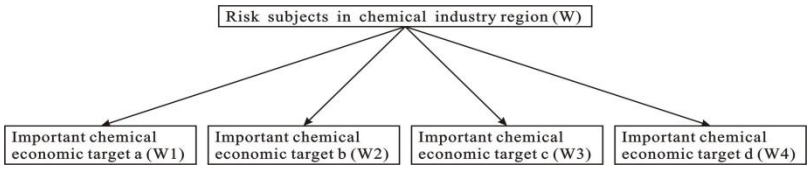

Fig. 3. Risk subject Break-down Structure

2) Risk event break-down

To break down a risk event into the risk break-down structure, is to find the risk factor in the risk event. A risk event and risk factors form a cause-and-effect relationship. Therefore, building the RBS is to build the causal relationship between risk event and risk factors. Terrorist attacks of major chemical industries may cause fire disasters, explosions and poison leakages. Possible secondary disasters may further lead to fire disaster thermal radiation (R1), explosive blast (R2), secondary explosive debris (R3) and poisonous and harmful substance spread (R4). These four risk events are our main references as is shown in Fig. 4.

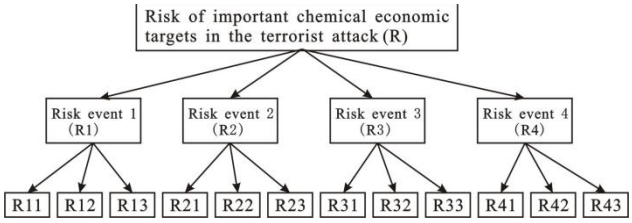

Fig. 4. Risk Break-down Structure

3) Constructing WBS-RBS Matrix to Identify the Risk in the Area

A WBS-RBS matrix composes of risk subject units (petrochemical industries A, B, C and D) and risk events (fire disaster thermal radiation (R1), explosive blast (R2), secondary explosive debris (R3) and poisonous and harmful substance spread (R4)), as is shown in Table IV. The matrix element's risk conditions and risk transitions are judged by experts and the feedback of questionnaires.

Risk conditions, in this case, can be high, middle or low. In the matrix element "0" shows that the subject unit corresponds to a low-risk event which has little influence and can be neglected. Element 0.5 shows that the subject unit corresponds to a middle-risk event. Element 1 shows that the subject unit corresponds to a high-risk event. All risk matrix elements should be "0", "0.5" or "1". After the estimation of every risk event condition, we add up the numerical values of all the risk events that may happen in the subject unit, according to which we can estimate the risk of the subject unit. This paper assumes the numerical values of risk in proportion to the risk occurrence possibility.

C. Analysis of Risk Evaluation of Nanjing

Taking Nanjing Chemical Industry Park as an example, we calculate and analyze the major chemical and petrochemical industries' risk identification. According to incomplete statistics, Jiangsu province has about 1300s petrochemical industries, four important national chemical industrial parks, which are respectively Nanjing Chemical Industrial Park, Nanjing Economic Development Zone Fine Chemical Industrial Park, Changzhou Binjiang Chemical Industrial Park and Nantong Chemical Industrial Park. Nanjing, as the capital of Jiangsu province, has the advantages of good location, good investment condition and a large market. Thus over 200 petrochemical industries are located in Nanjing. Through investigation and analysis, combining the characteristics of the petrochemical industries, this paper picks 18 representative petrochemical industries. These petrochemical industries are in great varieties, while they all adjoin the Yangtze River, and are concentrically located near the residential area. Terrorist attacks on them would easily trigger secondary disasters, and cause water pollution, and other persistent damage, which is a significant potential safety hazard.

According to the overall situation of the analysis objects, we select the concentrated area of petrochemical industries to identify the petrochemical industries in these areas as shown in Fig. 5.

Fig. 5. Important chemical industries cluster

In Nanjing Chemical Industry Park, the risk subject units are China Resources Gas Storage Tank Industry, Alkylbenzene Industry, Light Oil Gas Industry, NanJing Baijiang Liquid Gas Storage Tank Industry. Risk event units are fire disaster thermal radiation (R1), explosive blast (R2), secondary explosive debris (R3) and poisonous and harmful substance spread (R4). Based on the risk existence and the conditions of the risk translation, we build the WB-RBS matrix as is shown in Table IV.

TABLE IV. RISK EVALUATION IN THE CHEMICAL AREA

Item	*China Resources Gas Storage Tank Industry*	*Jinxiang Oil Company of PetroChina*	*Light Oil Gas Industry*	*NanJing Baijiang Liquid Gas Storage Tank Industry*
R_1	0.5	1	0.5	1
R_2	0.5	0.5	0.5	1
R_3	0	0.5	0.5	1
R_4	0.5	1	0.5	1
R	1.5	3	2	4

The results show NanJing Baijiang Liquid Gas Storage Tank Industry has the biggest comprehensive risk value, so it is the most vulnerable industry in terrorist attacks. The followings are Jinxiang Oil Company of PetroChina and then the Light Oil Gas Industry. Attack on China Resources Gas Storage Tank Industry produces the minimum influence.

I. CONCLUSIONS

The work analyzes the terrorist attack risks and possible disasters and damage types caused by petrochemical industries. We choose one of Nanjing's petrochemical industry parks as the study object. By analyzing their degrees of vulnerability and susceptibility to terrorist attacks, we use WBS-RBS method to identify their risk of getting attacked. The identification is expanded from a single target to multi-target clusters. The results prepare a theoretical basis for risk evaluation and control of petrochemical industries in China.

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