IOP Conference Series: Earth and Environmental Science

**PAPER** • **OPEN ACCESS**

# Quantitative Risk Assessment of Dangerous Goods Container Port

IOP Conf. Series: Earth and Environmental Science **580** (2020) 012094 doi:10.1088/1755-1315/580/1/012094

# Quantitative Risk Assessment of Dangerous Goods Container Port

**Chen Huang[1], Yu Bai[1] and Linlin Lu[2]**

[1] Tianjin Dongfang Tairui Technology Co., LTD., Tianjin, Tianjin, 300192, China

[2] Tianjin Research institute for Water Transport Engineering, M.O.T, Tianjin, Tianjin, 300000, China

**Abstract**: It may lead to extremely serious accidents once the risk of port operations of dangerous goods containers is out of control. To evaluate the risk of operation with complex processes and uncertain factors, this study proposes an evaluation method. This method uses the statistical analysis of the causes of related accident cases and the fishbone diagram method to obtain the risk assessment index set and uses the analytic hierarchy process to assign the evaluation index weight values. On this basis, we conduct case evaluation to verify the effectiveness of the method.

## 1. Introduction

Traditionally, port operations of dangerous goods containers include unloading, loading and yard storage operations. The main process during the operation is clear, and the man-machine surface is highly automated. Researchers generally consider that[1] the risk of port operations of dangerous goods containers is lower than that of road and rail transportation.

In the current study, researchers use rough set, BP (Back Propagation) neural network, index model, Monte Carlo method, Bayesian network and other methods to analyze and evaluate the risks of transportation operations[2-9], and focus on establishing evaluation index systems[10-12] in terms of characteristics of dangerous goods, transportation routes, transportation infrastructure, and technical conditions of transportation vehicles. The application of the above methods requires a long period of data collection and calculation. Therefore, this study will use AHP and FCE to propose a comprehensive evaluation model based on the likelihood and consequence severity of risk influencing factors.

## 2. Technical method

The technical method based on existing risk control theories, this paper proposes a comprehensive evaluation method of safety risk for port operations of dangerous goods containers that combines AHP and FCE[13-14]. It is more suitable for assessing operational risks with complex processes and many uncertain factors.

This study will make a statistical analysis of 116 cases of dangerous goods container port operation accidents similar to the Tianjin Port 8.12 Explosion, and use the fishbone diagram to find the factors that have a greater impact on the operational risk from the perspective of the cause of the accident, and establish a multi-level risk assessment indicator set.

## 3. Safety risk assessment of dangerous goods container port operations

### *3.1. Indicator system*

IOP Conf. Series: Earth and Environmental Science **580** (2020) 012094 doi:10.1088/1755-1315/580/1/012094

*3.1.1 Accidents causes analysis of dangerous goods container port operation.*
Direct cause analysis of 116 dangerous goods container port accidents in China from 2005 to 2018 (only one core factor is considered for each accident), details are shown in Table 1.

Table 1 Detailed description of the factors causing the accidents of dangerous goods container port.

| Cause | Number (Percentage) | Cause | Number (Percentage) |
|---|---|---|---|
| **Man(Management)** | 60(51.7%) | **Operating conditions** | 10(8.6%) |
| Not paying attention to the surrounding | 15 | Not clean and isolate inflammable and explosive materials | 3 |
| Operation against rules | 13 | Processing against rules | 2 |
| Not paying attention to self-safety | 13 | Environmental chaos, no protection, no supervision | 1 |
| Illegal crossing and walking | 8 | Illegal subcontracting | 1 |
| Blind rescue | 4 | No fire permit | 1 |
| Concealing dangerous goods | 2 | The gust of wind slammed the tarpaulin | 1 |
| Falling down | 2 | Lightning strike | 1 |
| Improper operation leads to collision | 2 | **Machine** | 23(19.8%) |
| Not wearing personal protective equipment | 1 | Fixture failure | 4 |
| Testing operation environment | 1 | Equipment failure | 3 |
| **Goods** | 23(19.9%) | Corrosion and rupture of pipeline | 3 |
| Unstable goods causes falling and collapsing | 13 | Drop of equipment parts | 2 |
| Remnant goods falling | 2 | Equipment overturning | 1 |
| Auto ignition | 5 | Equipment welding off | 1 |
| Goods reaction | 3 | Partial load fracture and collapse | 1 |
| | | Leak electricity | 1 |
| | | Elbow split | 3 |
| | | Others | 4 |

According to the statistical analysis, the causes of 116 accidents can be defined as "man (management)", "equipment", "goods", and "operating conditions".

*3.1.2 Risk identification based on fishbone diagram.*
In combination with the statistical analysis in Table 1, the "bone" in the fishbone diagram should include "man (management)", "equipment", "goods", and "operating conditions" as the main bones. Generally, during the operation of a port, the number and complexity of "equipment" are determined by the operation scale of the site. As an industry practice, the "equipment" factor is adjusted to the "operation scale". In addition, in accordance with Chinese laws and regulations related to the management of dangerous goods operations, "emergency capabilities" and "accident statistics" are statutory regulatory content. Therefore, the fishbone map has six fish bones. The content under each fish bone represents the specific elements involved in the cause of this type of accident. In theory, each element can independently lead to the occurrence of an operation accident, as shown in Fig. 1.

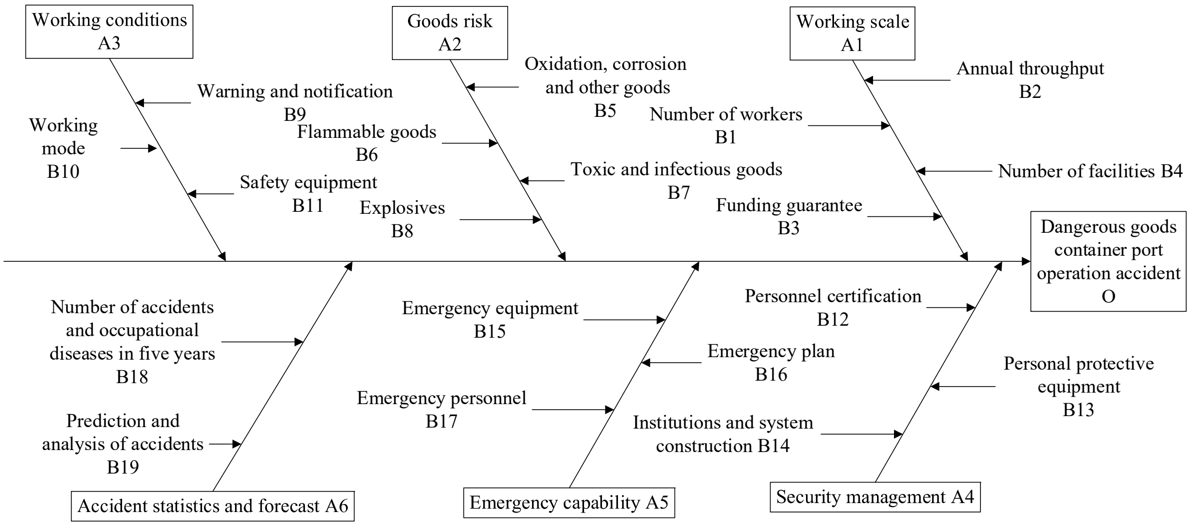


Fig. 1 Fishbone diagram for dangerous goods container port.

According to elements in fishbone diagram, this paper constructs a universally applicable risk assessment indicator set for port operations of dangerous goods containers, as shown in Table 4. The indicator system consists of six 1st-level indicators and 19 2nd-level indicators.

### *3.2. Weight distribution*

In the form of questionnaires, experts compared the importance of each level indicators in pairs, and the same level indicators were compared in pairs to construct a judgment matrix, and the consistency check was performed until "pass" to determine the weight of each indicator in the hierarchical indicator system. The weight vector and consistency check results of the evaluation model indicator set are shown in Table 2.

Table 2 Evaluation model indicator set global consistency check list.

| Level | A1 | A2 | A3 | Global CI | Global RI | Global CR | Whether to pass |
|---|---|---|---|---|---|---|---|
| | 0.083 | 0.070 | 0.189 | | | | |
| | A4 | A5 | A6 | | | | |
| | 0.193 | 0.227 | 0.238 | | | | |
| | Comprehensive weight | | | | | | |
| B1 | 0.014 | B11 | 0.108 | 0.040 | 0.491 | 0.081 | Yes |
| B2 | 0.015 | B12 | 0.028 | | | | |
| B3 | 0.023 | B13 | 0.055 | | | | |
| B4 | 0.031 | B14 | 0.110 | | | | |
| B5 | 0.008 | B15 | 0.112 | | | | |
| B6 | 0.013 | B16 | 0.071 | | | | |
| B7 | 0.017 | B17 | 0.044 | | | | |
| B8 | 0.031 | B18 | 0.079 | | | | |
| B9 | 0.027 | B19 | 0.159 | | | | |
| B10 | 0.054 | | | | | | |

### *3.3. Safety risk assessment*

#### *3.3.1 Situation of evaluation object.*

The study is conducted by a large container terminal company in Tianjin Port, China. The company has six 100,000-ton specialized container berths with an average annual dangerous goods throughput of 35,000 TEU, including class 2 (gases), class 3 (flammable liquids), class 4 (flammable solids, substances liable to spontaneous combustion), class 5 (oxidizing substances and organic peroxides), division 6.1 (toxic substances), class 8 (corrosive substance), and class 9 (miscellaneous dangerous substances and articles, including environmentally hazardous substances).

*3.3.2 Fuzzy evaluation process.*
Set the comment set $V$= {good, better, moderate, poor, unacceptable} ($n$=5). The 100 experts invited in this study evaluated 19 2$^{nd}$-level evaluation indicators based on port operations of dangerous goods container condition of above-mentioned companies, and used the number of reviews obtained by each indicator to form a fuzzy mapping relationship and fuzzy matrix. According to fuzzy matrixes, the fuzzy comprehensive evaluation vector of dangerous goods container port operations of the company is calculated by using comprehensive weight vectors in Table 2 as:

$$R=\begin{pmatrix} 0.054 & 0.102 & 0.357 & 0.361 & 0.028 \\ 0.100 & 0.374 & 0.350 & 0.176 & 0.000 \\ 0.157 & 0.320 & 0.486 & 0.000 & 0.000 \\ 0.072 & 0.257 & 0.443 & 0.228 & 0.000 \\ 0.000 & 0.082 & 0.230 & 0.397 & 0.167 \\ 0.333 & 0.500 & 0.167 & 0.000 & 0.000 \end{pmatrix}$$

$$B=\omega\cdot R=(0.134, 0.283, 0.323, 0.176, 0.04)$$

*3.3.3 Quantitative embodiment and analysis of assessment results.*
To better quantify the security risk level of port operations of dangerous goods containers, we set a clear score set C for the comment set, and design the comment set interval as shown in Table 3. The degree of risk can be quantitatively reflected by the mapping relationship between the fuzzy comprehensive evaluation vector and the comment set.

Table 3 Comprehensive evaluation risk level.

| Comment set | Best | Better | Moderate | Poor | Unacceptable |
|---|---|---|---|---|---|
| Fuzzy mapping score $C$ | 95 | 85 | 75 | 65 | 30 |
| Safety risk comment set score interval | [100，90] | （90，80] | [80，70] | （70，60] | （60，0] |

Using the results of the above table, we can calculate the quantitative value of the safety risk level of dangerous goods container port operations of the company. According to the mapping relationship in Table 3, it can be concluded that the security risk level is moderate. The evaluative quantitative scores of the 1$^{st}$-level indicators and the 2$^{nd}$-level indicators can also be obtained, as shown in Table 4.

Table 4 Evaluation quantitative score of the 2$^{nd}$-level indicator.

| 1$^{st}$-level indicator | Quantitative score $F$ | Evaluation result | 2$^{nd}$-level indicator | Quantitative score $F$ | Evaluation result |
|---|---|---|---|---|---|
| Working scale A1 | 73.3 | Moderate | Number of workers B1 | 84 | Better |
| | | | Annual throughputB2 | 72 | Moderate |
| | | | Funding guarantee B3 | 66.5 | Poor |
| | | | Number of facilities B4 | 74 | Moderate |
| Goods risk A2 | 79.0 | Moderate | Oxidation, corrosion and other goods B5 | 84 | Better |
| | | | Flammable goods B6 | 77 | Moderate |

| | | | | | |
|---|---|---|---|---|---|
| | | | Toxic or infectious goods B7 | 78 | Moderate |
| | | | Explosives B8 | 79 | Moderate |
| Working conditions A3 | 82.1 | Better | Warning and notification B9 | 83 | Better |
| | | | Working modeB10 | 80 | Better |
| | | | Safety equipmentB11 | 83 | Better |
| Security management A4 | 76.7 | Moderate | Personnel certification B12 | 83 | Better |
| | | | Personal protective equipment B13 | 83 | Better |
| | | | Institutions and system construction B14 | 72 | Moderate |
| Emergency capability A5 | 64.3 | Poor | Emergency equipment B15 | 64.5 | Poor |
| | | | Emergency plan B16 | 75 | Moderate |
| | | | Emergency personnelB17 | 47 | Unacceptable |
| Accident statistics and forecast A6 | 86.7 | Better | Number of accidents and occupational diseases in five years B18 | 92 | Best |
| | | | Prediction and analysis of accidents B19 | 84 | Better |

## 4. Conclusions

This research proposes a risk analysis and assessment method for port operations of dangerous goods containers. The conclusions are as follows:

1) The statistical analysis of accident cases and the combination of fishbone diagrams can intuitively reflect the impact of accident causes on operational risks, which is conducive to discovering accident rules for container operations in dangerous goods ports and establishing a systematic evaluation index set.
2) The comprehensive application of the analytic hierarchy process and the fuzzy comprehensive evaluation method can perform risk assessment on operations with complex processes and many uncertain factors, and simplify the amount of data and calculation scale, and the evaluation results have intuitive guidance for risk control.
3) The confirmatory evaluation in this study belongs to the problem of small sample sets. To ensure the accuracy of the evaluation, industry experts are invited to carry out fuzzy evaluation, which can ensure the robustness of the risk evaluation results.

## Acknowledgments

Fundamental Research Funds for the Central Public Welfare Research Institutes (Grant no. TKS180206)， Tianjin Science and Technology Supporting Key Project(17YFZCSF01250).

## References:

[1] Cabral A M R, Ramos F D S. Cluster analysis of the competitiveness of container ports in Brazil [J]. *Transportation Research Part A: Policy and Practice* 2014; 69: 423-431.
[2] Bagheri M. Risk analysis of stationary dangerous goods railway cars: a case study [J]. *Journal of Transportation Security* 2009; 2(3): 77-89.
[3] Gao Qing-ping. Risk analysis for hazardous materials transportation based on rough set theory [J]. *China Safety Science Journal* 2011; 21(11): 103-108.
[4] Li Yan, Cheng Dong-hao. Du Jun. Study on dynamic Safety appraisal of airway transportation of hazardous cargoes based on BP neural network [J]. *Logistics Technology* 2012; 36(3): 71-77.
[5] Chen Yue, Zhang Yu-ling. Study on risk evaluation and management for road transport of

dangerous goods based on index model [J]. *Journal of highway and transportation research and development* 2018; 35(3): 143-150.

[6] Caliendo C, Guglielmo M L D. Quantitative Risk Analysis on the Transport of Dangerous Goods through a Bi-Directional Road Tunnel [J]. *Risk Analysis an Official Publication of the Society for Risk Analysis* 2016; 37(1): 116.

[7] Tomasoni A M , Garbolino E , Sacile R , et al. Risk evaluation of real-time accident scenarios in the transport of hazardous material on road[J]. *Management of Environmental Quality an International Journal* 2010; 21(5): 695-711.

[8] He Ya-tian, Zhang Xiao-yuan. Application of Monte-Carlo Method to the Risk Assignment of Hazardous Materials during Road Transportation [J]. *Safety and Environmental Engineering* 2009; 16(3): 101-103.

[9] Yang Neng-pu, Yang yue-fang, Feng Wei. Risk assessment of railway dangerous goods transport process based on fuzzy Bayesian network [J]. *Journal of the China railway society* 2014; 36(7): 8-15.

[10] Yuan Yuan-chun, Liu Hao-xue, Zhang Yong, et al. A methodology for Safety assessment of hazardous Material road transport enterprises based on fuzzy TOPSIS [J]. *China Safety Science Journal* 2010; 20(9): 32-37.

[11] Shen xiao-yan, Liu Hao-xue, Xie pei. A Safety Assessment model for hazardous Material Enterprise based on principle component analysis [J]. *China Safety Science Journal* 2012; 22(1): 124-130.

[12] Luan Ting-ting, Guo Zhan, Pang Lei, et al. Early warning model for risks in railway transportation of dangerous goods based on combination weight [J]. *Journal of the China railway society* 2017; 39(12): 1-7.

[13] Semil Onut, Umut R. Tuzkaya, Ercin Torun. Selecting container port via a fuzzy Study in the Marmara Region, Turkey [J]. *Transport Policy*, 2010, 18(2011):182-193.

[14] Zhang Shukui, Lu Ziai. Fuzzy judgment for port security and safety based on AHP [J]. *Journal of Jiangsu University of Science and Technology (Natural Science Edition)*, 2011, 25(1):14-16.