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Simulation Analysis for Evaluating Dangerous Cargo in Port

Yong Seok Choi, Eun Ju Kim

Sunchon National University, South Korea

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1. Introduction

Risk by Dangerous Cargo in Port

- The risk of disasters such as earthquake and subsequent safety accidents in Kumamoto Prefecture has increased.
- In the port area, 171 people were killed, 12 people were missing, 700 people were injured and 6 thousand people were injured in Tianjin port explosion in August 2015.

Evaluation of Risk in Port

- As the international community continues to increase international trade volume and raise awareness of security and safety, it is increasingly strengthening the management and control of hazardous materials.
- Systematically discuss the efficient management of hazardous cargo in the port, including the improvement of domestic laws and systems and prevention of accidents.
- To analyze the problems of the port hazardous materials management system in Korea and to improve the port hazardous materials management in order to improve the safety management system of dangerous goods in the port of Korea.

2. Derivation of Port Dangerous Factor

In case of port, the amount of damages due to safety accidents reaches an average of 123.06 million won per year. Such safety accidents have various types of accidents, and port safety accidents have caused deterioration in port operation efficiency and many economic losses.

Accident status by type of hazardous material

Division	Property	Number of accidents by type of dangerous goods	
		2015	2014
Category 1	Oxidizing solid	0	0
Category 2	Combustible solid	1	2
Category 3	Pyrophoric substances and gold-water-based substances	3	3
Category 4	Flammable liquid	76	54
Category 5	Self-reactive material	1	1
Category 6	Oxidizing liquid	2	1
Etc		2	1
Sum		85	62

Type	Fire	Explosion	Leakage	Sum
2015	53	13	19	85
2014	32	10	20	62
Sum	85	23	39	147

2. Derivation of Port Dangerous Factor

We present the relative severity and risk of each accident by analyzing the status of hazardous material accidents in the port.

Severity = Damage Amount ÷ Number of Accidents

Risk = Frequency of Occurrence × Severity

Hazard rating by cause of dangerous goods accident

Cause of accident	Number of Accidents (2 years)	Annual Incidence	Amount of Damage (one million won)	Severity Rating	
				Severity	Risk
Human Factors	77	38.5	1637.1	21.3	818.6
Physical Factors	29	14.5	1775.5	61.2	887.8
Other Factors	28	14	385.1	13.8	192.6
Unknown Cause	13	6.5	4189.4	322.3	2094.7

The severity and the risk level for the risk assessment based on the number of accidents, frequency, and amount of damage by the cause of the hazardous material accidents in the last two years. The severity of the risk was the highest in cases of unknown cause, followed by physical factors, human factors, and other factors. The risk was in descending order of unknown cause, physical factors, human factor, and other factors.

The annual incidence is low at 6.5, but the amount of damage per accident is as high as 3.49 million dollar, so the severity is high and the risk is very high.

2. Derivation of Port Dangerous Factor

In order to convert the causes of hazardous material accidents into factors for management, three factors such as human resource management, S/W management, and H/W management, which are classification standards understood by the port practitioners.

- The AHP(Analytic Hierarchy Process) analysis was conducted to evaluate the dangerous goods risk assessment action as an evaluation factor and to evaluate the priority according to the importance of these factors.

- Based on the results of surveys received from the port hazard experts, weights and priorities of the detailed evaluation items were derived.

Measurement Objective	Evaluation Factor	Main Content	Detailed Evaluation Items
Dangerous Goods Risk Evaluation	Human Resources (HR) Management	Management aspects of human resources in hazardous material risk assessment activities	Strengthen safety education
			Improve management personnel
			Secure managerial proficiency
	S/W Management	Management of software activities during hazardous material risk assessment activities	Supplementing the operating system
			Safety manual supplement
			Related program development
	H/W Management	Management of hardware activities during hazardous material risk assessment activities	Supplementing dangerous goods facilities
			New introduction of management equipment
			Improve management equipment performance

3. AHP for Hazardous Material Management Level Setting

Selection of detailed evaluation items

- Importance Evaluation of detailed evaluation items(5 points Lickertis scale)
- Exemption the under 80% in ratio of responses
- Expert panel survey
- Carry out a survey targeting field experts worked in port container terminal

First tier analysis result

Evaluation Factor	Importance	Consistency Index
Human Resources (HR) Management	0.543	0.00699
S / W management	0.244	
H / W management	0.213	

As a result of the consistency test of the respondents, 0.00699, which is less than 0.1, showed consistency. In the case of importance, human resource management was the highest with 0.543, followed by S/W management 0.244 and H/W management 0.213.

3. AHP for Hazardous Material Management Level Setting

Weights and priorities for detailed evaluation items

Key Factors	Detailed Evaluation Items	Importance	Priority	Consistency Index
Human Resources (HR) Management	Strengthen safety education	0.176	2	0.00
	Improve management personnel	0.157	3	
	Secure managerial proficiency	0.222	1	
S/W management	Supplementing the operating system	0.100	4	
	Safety manual supplement	0.070	6	
	Related program development	0.064	7	
H/W management	Supplementing dangerous goods facilities	0.087	5	
	New introduction of management equipment	0.060	9	
	Improve management equipment performance	0.064	7	

As a result of the consistency test, the consistency index of the detailed evaluation items for each evaluation factor was less than 0.1 and consistency was secured.

4. Development of Risk Assessment Model

Risk is composed of quantified values of the frequency of accidents and the severity of accidents.

Frequency, severity, risk criteria

Frequency		Severity		Risk	
F1	< 10	S1	< 20	R1	< 400
F2	< 20	S2	< 40	R2	< 600
F3	< 30	S3	< 60	R3	< 1000
F4	< 40	S4	< 80	R4	< 1500
F5	< 50	S5	< 100	R5	< 2200

Matrix structure risk grading criteria and results

division		Severity				
		S1	S2	S3	S4	S5
Frequency	F1	R1	R2	R2	R3	R4
	F2	R1	R2	R3	R3	R5
	F3	R2	R3	R4	R5	R5
	F4	R3	R3	R5	R5	R5
	F5	R3	R5	R5	R5	R5

4. Development of Risk Assessment Model

The risk numbers multiplied by the incidence frequency and the severity, and the risk grades of the matrix structure method. As a result, **human factors were R3**, **physical factors were R3**, and **other factors were R1**. When we look at the characteristics of each factor, the other factors are low in occurrence frequency and the severity is the lowest. Human factors go into a criterion with a high frequency but a low severity. Physical factors enter a criterion of high severity with low occurrence frequency. Unknown causes are included in the areas where the importance is low, but the severity is the highest.

Therefore, the cause of the unknown is relatively low, but the severity is high, so it is judged to be one step higher than the risk grade in the matrix structure risk grade judgment.

Comparison of the results of the risk grading

division	Risk Level Scale	Matrix Structure	Judgment
Human factors	R3	R3	Same
Physical factor	R3	R3	Same
Other factors	R1	R1	Same
Unknown cause	R5	R4	No match

5. Simulation Analysis

The results of the Monte Carlo simulations for risk assessment showed no significant differences in the amount, severity, and risk of injury to human and physical factors, but other factors such as damage amount, severity, and risk were relatively low.
The amount of damage, severity, and risk were considerably high, indicating that priority management was required.

Hazardous material accident causes and hazards

Cause of Accident	Hazardous Material Accident Data Analysis Value			Simulation Result Value		
	Amount of Damage	Severity	Risk	Amount of Damage	Severity	Risk
Human Factors	1637.1	21.3	818.6	820.2	21.7	410.1
Physical Factor	1775.5	61.2	887.8	812.3	21.4	406.1
Other Factors	385.1	13.8	192.6	196.4	14.0	98.2
Unknown Cause	4189.4	322.3	2094.7	2126.0	350.5	1063.0

We compared the analysis results of the data on the hazardous material accidents and the simulation results. The severity was high in simulation results, human factor, other factors, unknown cause, and the risk was low in simulation results.

6. Conclusion

The factors for improvement of port hazardous materials safety management were selected and the importance and priority of those factors among various improvement plan factors were analyzed through AHP analysis.

The characteristics of each type of dangerous material accident occurrence are considered to be the lowest and the severity of the accident is low.

- **Human factors go into a criterion with a high frequency but a low severity.**
- **Physical factors enter a criterion of high severity with low occurrence frequency.**
- **Unknown causes are included in the areas where the importance is low, but the severity is the highest.**

The results of the Monte Carlo simulations for risk assessment showed no significant differences in the amount, severity, and risk of injury to human and physical factors, but other factors such as damage amount, severity, and risk were relatively low.

We compared the analysis value of the data on the hazardous material accident and the simulation result, the severity was high in the simulation result, human factor, other factors, unknown cause, and the risk was low.

It can be seen that the risk of a port hazardous material accident is estimated to be relatively lower than that of a hazardous material accident data through a simulation experiment.