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A Study on the Relational Analysis of Human Errors in Railway Accidents*

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Abstract

Purpose: This study examines the persistent occurrence of railway accidents despite numerous safety devices, highlighting the multifaceted nature of these incidents. **Research design, data and methodology:** Utilizing the 4M analysis method, the research investigates a decade's worth of accident reported from the Aviation and Railway Accident Investigation Board to identify risk factors and suggest mitigation measures. **Results:** The analysis reveals that 57% of railway accidents are attributed to human factors, followed by mechanical (28%), environmental (7%), and management (8%) factors. **Conclusions:** The study underscores the necessity of prioritizing safety and establishing a unified organizational approach to prevent human error accidents. It calls for an alignment of risk perception between headquarters and field operations, advocating for educational and perceptual changes, as well as systematic improvements to achieve safety goals.

Keywords : Risk Assessment, Railway Accident, 4M(Man, Machine, Media, Management), Human Error

JEL Classification Code : J28, L92, R41

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1. Introduction

1.1. Background of Research

Looking at the statistics of domestic railway accidents, it can be seen that they have occurred every year in the form of derailment, collision, etc., leading to physical and human losses (TS, 2023) (see Table 1).

In the event of problems due to system errors, mechanical defects, natural disasters, and insufficient management levels, railway accidents are likely to occur due to various factors linked to each other, so preventive measures are needed for each factor.

By applying the 4M technique used to analyze the cause of the accident, this study aims to systematically present the potential harmful risk factors in each work based on the recent 10 years of railway accident investigation report data reported to the Aviation and Railway Accident Investigation Board.

Table 1: Death and Injuries and Property Damage

Year	Death toll	number of injured	Property damage (KRW 1 million)
2012	2	268	638
2013		35	18,191
2014	1	281	8,073
2015			3,258
2016	1	8	170,336
2017	1	6	6,937
2018		1	121
2019		2	407

1.2. Research Objectives

Domestic railway accidents have been analyzed and presented in various ways, such as railway workers and passengers, but in recent years, human factors such as railway workers and passengers have been analyzed and presented rather than these technical problems due to the strengthening of management supervision and management technology.

The reason for the decreasing trend in domestic railway accidents can be seen as the continuous efforts to reduce accidents. The best measure to prevent accidents by thoroughly analyzing the cause of such accidents can be seen as a way to reduce the occurrence of such accidents, and the recent reality is that the importance of accident prevention measures is increasingly being emphasized. Therefore, the purpose of this paper is to conduct a systematic analysis of the cause of railway accidents using the 4M analysis technique, and to establish and present new reasonable preventive measures.

2. Literature Review

2.1. Railway Accident Investigation

2.1.1. Items Subject to the Korea Railway Accident Investigation

The investigation of domestic railway accidents aims to contribute to the prevention and safety of aviation accidents and railway accidents by accurately identifying the cause of accidents through an independent and fair investigation into aviation accidents and railway accidents in Korea under the Aviation and Railway Accident Investigation Act. In this study, it was limited to railway accidents, and the target is an accident in which human thoughts or materials were damaged during the operation of a railway vehicle or train, as shown in Table 2 (ARAIB, n.d.).

Table 2: Items Subject to Railway Accident Investigation

Items subject
1) Train crash/dismantling accident
2) An accident in which a fire broke out in a railway vehicle or train and the operation was suspended
3) An accident in which three or more casualties occurred in connection with the operation of a railway vehicle or train
4) An accident in which property damage of more than 50 million won occurred in connection with the operation of a railway vehicle or train

2.1.2. Classification of Korean Railway Accidents

In the Guidelines on Reporting Railway Accidents (hereinafter referred to as Accident Reporting Guidelines), it is largely classified as 'railway accident', 'operation obstacle', and 'railway disaster'. A 'railway accident' is a damage to a person's thoughts or objects in connection with the operation of a railway or the management of a railway facility. A 'operation obstacle' means that it interferes with the operation of a railway vehicle and does not fall under a railway accident. Finally, a 'railway disaster' is based on damage to a railway facility or a railway vehicle due to a disaster. The classification and definition of this are as shown in Table 3(KR, 2014).

Table 3: Classification Standards

Classification				Accident
Railway Accident	Railway traffic accidents	Train accident	Train crash	An accident in which a train has been suspended due to collision or contact with another train (railway vehicle) or obstacle
			Train derailment	An accident in which the wheels of the railway vehicles constituting the train deviated from track and derailed
			Train fire accident	An accident in which a fire broke out on a train, causing casualties or suspending the operation of the train
			Other train accidents	An accident in which dangerous or dangerous objects leak or explode from a train, causing casualties or property damage
		Crossing accident		Accidents that collide or come into contact with a train or railway vehicle and any other means of transportation that passes through the road at the crossing
		Railway traffic accidents	passenger	Accidents in which passengers, public, and employees were killed or injured due to the operation of trains or railway vehicles, not accompanied by train collisions, train derailments, train fires, or other train accidents
			public	
			employees	
	Railway safety accident	Railway fire accident		Fire in railway facilities such as station, machine room, etc. or railway vehicles
		Railway safety accidents	passenger	Accidents in which passengers, the public, and employees were killed or injured due to falls, electrocution, and shocks in railway facilities such as waiting rooms, platforms, and tracks, not accompanied by railway fire accidents or damage to railway facilities
			public	
			employees	
		Railway facilities damage accident		An accident in which railway facilities such as bridges, tunnels, tracks or signals, electrical and communication facilities are damaged
		Other railway safety accidents		Accidents that do not fall under the accident of a railway fire accident, a railway safety accident, or a railway facility damage accident
Driving disability	Dangerous incident	What is likely to develop into a railway accident • When a train is driven for the purpose of operating a section that is not permitted to operate • When a signal instructing the train to proceed is displayed despite the obstruction of the course in which the train intends to operate • When the train passes a stop signal and interferes with the course of another train or railway vehicle • Train or rail vehicle rolled over station and station • When a train is driven in a section where the operation of the train is suspended and construction or repair work is carried out • When a railway vehicle derailed from a side line interferes with the main line		
				• In the event of a breakdown, damage, etc. of railway facilities such as tracks and signal devices that interfere with the safe operation of the train • In the event of a breakdown, damage, etc. of a railway vehicle, such as a driving device or braking device that interferes with the safe operation of a train • When hazardous materials such as explosives are leaked from a train or railway vehicle • In accordance with the above
		Delayed operations		When the departure and arrival stations are delayed from the planned time table, or between stations and stations, they are delayed from the driving test • High-speed trains and electric trains take more than 10 minutes • 20 minutes or more for regular passenger trains • Freight and other trains longer than 40 minutes
Railway disaster	Damage to railway facilities or railway vehicles due to disasters (natural disasters, social disasters)			

2.1.3. China

China has a four-stage accident rating system and is classified according to the degree of human damage and the degree of disruption to the operating line. The subjects of the investigation are also divided into subjects by accident level. Details are shown in Table 4 below (Park, 2021).

Table 4: China Railway Accidents Standards

Sortation	Situation	Investigation subject
Special serious accident	• More than 30 people deaths, serious injuries or direct economic losses of more than 100 million yuan • More than 18 passenger trains derailed and the railway was suspended for more than 48 hours • More than 60 express freight trains derailed and the railway was suspended for more than 48 hours	State Council
Serious accident	•More than 10 and less than 30 deaths, 50 and less than 100 serious injuries, or economic losses of more than 50 million yuan and less than 100 million yuan • More than 18 passenger trains derailed • More than 60 freight trains derailed • 2 or more passenger trains and less than 18 passenger trains derailed, and the main line is suspended for more than 24 hours and less than 48 hours • 6 or more freight trains and less than 60 freight trains derailed, and the main line is suspended for more than 24 hours and less than 48 hours	Railway department under the State Council
Shift accident	• 3 or more and less than 10 deaths, 10 or more seriously injured and less than 500 serious injuries, or economic losses of more than 10 million yuan and less than 500 million yuan • More than 2 passenger trains and less than 18 passenger trains derailed • More than 6 freight trains and less than 60 freight trains derailed • Suspension of main lines for more than 6 hours • Suspension of other lines for more than 10 hours	Organization of Railway Management Organization in Accident Area
General accident	• 3 or less deaths, less than 10 serious injuries, or less than 10 million economic losses ※ The Railway Administration Office under the State Council may supplement other situations of general accidents in addition to the provisions of the preceding paragraph	

2.1.4. Japan

In the case of Japan, it is divided into a serious accident and an incident, and it is required to investigate the accident that occurred and to report and investigate the situation where the probability of the accident is sufficient. The contents of the Japanese railway accident standards are shown in Table 5 below(Park, 2021).

Table 5: Japan Railway Accidents Standards

Sortation	Situation		
Serious accident	Train crash	Train crashes or encounters with other trains or vehicles	
	Train derailment	An accident in which a train derailed	
	Train fire accident	an accident in which a train caught fire	
	crossing a disability accident	An accident in which a train or vehicle collides with or comes into contact with a person or vehicle passing through the road on a crossing road	- causing fatalities such as passengers, flight attendants, etc - causing more than five deaths
	road accident	An accident in which a train or vehicle collides with or comes into contact with a person or vehicle passing through a road on a road other than a crossing road	- It was caused by the occurrence of a crossing road where a crossing breaker was not installed, resulting in death
	Railway Manipulation Accident	an accident that caused casualties by the operation of a train or vehicle	- The cause of death is deemed to be a cause of an error in handling by railway officials or failure, damage, destruction, etc. of vehicles or railway facilities
	Railway damage accident	An accident in which physical damage of more than 5 million yen was caused by the operation of a train or vehicle the state of affairs	
Situation	When a train is driven to drive in the closed section because the closed handling is completed - a situation in which another train or vehicle exists in the section		
	A signal indicating the progress of the train or a signal indicating the progress of the train during the presentation of the signal indicating the progress of the train despite obstructing the course of the car - a train entering the course of the train		
	A situation in which a train burns a stop signal and the train interferes with the course of another train or vehicle on the main line - a situation in which another train or vehicle has entered the protected area of the traffic light that protects the section of the course		
	Failure, damage, destruction, etc. impeding the safety of train operation, such as railway driving security facilities - failure, damage, destruction, etc. with a particularly significant risk of train collision, derailment, or fire		
	Failure, damage, destruction, etc. impeding the safety of train operation, such as vehicle driving devices, brakes, electrical devices, connections, driving security facilities, etc. - Failure, damage, destruction, etc. with a particularly significant risk of train collision, derailment or fire		
	• Especially something that is recognized as unusual		

2.1.5. EU

In the EU, a train collision, derailment, or accident with a clear impact on railway safety regulations or safety management results in one or more deaths, five or more serious injuries, or serious damage to rolling stock, equipment or the environment. Therefore, if damage exceeds 2 million euros occurs, it is considered a serious accident and an accident investigation is conducted.

2.2. Type of Accident

As a result of analyzing the types of accidents in the air rail accident investigation report, 52 derailed accidents caused by wheel dislocation out of a total of 74 accidents, as shown in Table 6, did not lead to human damage, but property damage occurred.

Table 6: Types of Railway Accident Occured

Sortation	Number of accidents	note
Train crash	6	
Train derailment	52	
Train fire accident	4	
Collision-de-line collision	4	
Other	6	

2.3. 4M Technique

The 4M technique is a method used in deriving risk factors, which is the second stage of the risk assessment process, to find harmful and risk factors and to establish measures to minimize the possibility of the harmful and risk factors developing into accidents(KOSHA, 2008).

3. Research Methods and Materials

This study analyzes the harmful and risk factors of railway incidents and accidents that have occurred over the past 12 years (2011-2022) based on the report of the Railway and Aviation Investigation Board. It classifies accidents into four factors(human factors, mechanical factors, environmental factors, and management factors) through the 4M technique to identify the key causes for each factor, analyze the results of each cause, establish safety measures in response to them, and suggest systematic improvement measures.

4. Results and Discussion

4.1. Configuring 4M Assessment Items

The evaluation items were classified into four categories: 4M(Man factor, Mechanical factor, Environmental factor, and Management), and each cause was classified into detailed factors again, and each factor is shown in Table 7(KOSHA, 2007).

Table 7: Classification of Dangerous Events

Factor	Assessment
Human (Man) Factors	• Lack of individual qualifications • Inadequate supervision, schedule/planning • Confusion of organizational target values • Lack of safety culture
Mechanical factors	• Faulty warning device • Lack of inherent safety design • Default protection system • Poor condition (defects in the structure of the machine) • Defects in the structure of the facility • Fatigue crack
Environmental (Media) Factors	• Climate • Noise, communication status • Vibration
Management factors	• Absence of regulations and manuals

4.2. 4M Assessment

4.2.1. Human (Man) Factors

4.2.1.1. Cause

As a result of the analysis of human errors in serious railway accidents, the core causes are lack of individual qualification ability, inadequate management supervision or planning, confusion of organizational target values, and safety culture(KOSHA, 2007).

Table 8: Major Cause of Human Error

Sort	Cause
Key cause of human error	1) Lack of individual qualification (selection, education and training, verification) - Failure to comply with business procedures (safety monitoring, train protection, signal verification, etc.) (causing speculation, confusion, illusion, oblivion, etc.) - Lack of human performance/skills (insufficient education and training) - Lack of non-technical skills such as communication/risk information exchange (wrong decision making) (2) Inadequate supervision, schedule/planning - excessive work schedule/planning/promotion - Allowing unqualified persons, performing inappropriate tasks - Strengthen safety monitoring and management supervision (3) Organization's target value confusion - Lack of target value of safety priority - Lack of safe investment (4) Lack of safety culture - Lack of compliance with rules, lack of emergency response capabilities - Voluntary risk monitoring, lack of continuous safety inspection/confirmation activities - leadership, lack of self-esteem

4.2.1.2. Cause-specific Classification Results

According to the classification of incidents and accidents based on the core causes of lack of individual qualifications, inadequate management supervision or planning, confusion of organizational target values, and safety culture, 28 accidents due to lack of individual qualifications, 19 inappropriate management supervision or planning, 18 accidents due to organization's target value confusion, and 32 accidents due to lack of safety culture.

4.2.2. Mechanical Factors

4.2.2.1. Cause

As a result of the analysis of mechanical errors for serious railway accidents, the key causes are defects in warning devices, lack of essential safety design, poor protection devices, mechanical structural defects, facility structural defects, and fatigue cracks(KOSHA, 2007).

Table 9: Major Cause of Mechanical Error

Sort	Cause
Key cause of mechanical error	1) a defect in the structure of the equipment - a defect in the structure of the equipment - a defect in the protection system 2) mechanical defect - If you can't withstand the frictional heat due to poor condition and it melts - a fissure of fatigue 3) Fault in the warning device - Human error due to absence of warning device - A fault in the warning device causes a human error

4.2.2.2. Cause-specific Classification Results

As a result of classifying incidents and accidents due to warning device defects, lack of essential safety design, protection device defects, mechanical structural defects, facility structural defects, and fatigue cracks, three accidents due to warning device defects, one lack of essential safety design, five protection device defects, 20 mechanical structural defects, 12 facility structural defects, and seven fatigue cracks, the largest number of mechanical structural defects.

4.2.3. Enviromental (Media) Factors

4.2.3.1. Cause

As a result of the analysis of environmental errors for serious railway accidents, the key causes are climate-induced accidents, casualties caused by noise/communication conditions, and device errors caused by vibration, and the main contents of each key cause of railway accidents derived in this study are shown in Table 10(KOSHA, 2007).

Table 10: Major Cause of Environmental Error

Sort	Cause
key cause of environmental error	1) harmful/hazardous factors due to climate - Accidents caused by increased electrical conductivity due to humid climate - Difficulty in securing visibility due to rain, snow, etc (2) casualty accidents caused by noise and communication conditions - Difficulty identifying safety signals due to noise - Difficulty identifying signals due to poor communication (3) Instrument error due to vibration

4.2.3.2. Cause-Specific Classification Results

Nine accidents caused by climate, two accidents caused by noise/communication conditions, and one accident caused by vibration were classified as the main causes of climate accidents.

4.2.4. Management Factors

4.2.4.1. Cause

As a result of the analysis of management errors for major railway accidents, it was found that most of the core causes were not able to respond because there were no systems and manuals. In the event of the same accident afterwards, it seems that it is possible to respond by creating and using related manuals.

4.2.4.2. Cause-specific Classification Results

There were a total of 13 incidents and accidents caused by management factors**.**

5. Conclusions

In this study, by analyzing the data of the Aviation and Railway Accident Investigation Board for the past 12 years, the accident type and accident factors were identified, and preventive measures for them were examined. First of all, in the analysis of railway accidents, most of the human factors were 57%, and mechanical factors were 28%, environmental factors 7%, and management factors were 8%.

There was a total of 97 human factors, 19.5% of which were inappropriate management, supervision, or planning, 18.5% of which were organizational target value confusion, and 62% of which were safety culture and lack of individual qualification.

There was a total of 48 mechanical factors, of which 12 accidents were caused by design standards and structural

problems, accounting for 25%, and 27 accidents caused by damage to railway parts, accounting for 56%.

In conclusion, this study summarizes and presents three main points for countermeasures against railway accidents.

First, most of the railway accidents occur due to lack of safety culture and individual qualifications among human factors, as shown by the analysis of the cause of the railway accident. Unlike driving with concentration of consciousness, engineers are more likely to cause human errors due to relatively low concentration of consciousness or change of consciousness by driving only on equipped tracks, as drivers are exposed to various risks in road traffic. In order not to omit or go wrong, the railway accident education program must include the factors of safety accidents so that the importance of consciousness and procedures can be continuously recognized.

Second, among mechanical factors, a manual is presented separately for accidents caused by design criteria and structural problems, so that they can be recognized as signs while driving, so that they can be careful when passing through the area.

Lastly, the first priority should be to give safety-first goal value and to form a consensus for the entire organization. An organizational vision and feasible safety goals and implementation plans are needed. In addition, the corresponding compensation policy should be implemented in accordance with fair procedures to continuously promote the goals of safety top priority. In order to achieve these goals, it is necessary to reduce the difference in the risk of human error recognized by the headquarters and the field, and it can be said that education and perception changes are needed to reduce this difference, and systematic supplementation should be required.

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