Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 218 (2016) 131 – 140
Procedia
Social and Behavioral Sciences

11th International Conference of The International Institute for Infrastructure Resilience and Reconstruction (I3R2)
: Complex Disasters and Disaster Risk Management

A Factor Analysis of Urban Railway Casualty Accidents and Establishment of Preventive Response Systems

Kim, Hyun ju[a], Jeong, Ja young[a*], Kim, Jang wook[a], Oh, Jae kyung[b]

[a] *Management Research Department KORAIL Research Institute, 240, Jungangro, Dong-gu, Daejeon City, 300-720, South Korea*
[b] *Seoul National University of Science & Technology, 232 Gongneung-ro, Nowon-gu, Seoul, 139-743, South Korea*

Abstract

Since the commencement of urban railways in 1974 and KTX service in 2014, the use of railways has been steadily increasing. The number of people using rail transportation has been steadily rising. As a result, this has also led to an increase in the number of passenger-related accidents that are occurring within railway stations. In an effort to prevent such accidents, much of the rail operation system is now automated. Nevertheless, the potential risks of railway accidents are very much present today. This study has utilized the railway accident databases of rail operators to allow for analysis of different types of railway accidents, age of accident victims, gender of accident victims, pedestrian facilities involved in accidents, passengers involved in accidents, and underlying causes of rail accidents. Based on these statistics and analyses, this paper proposes the development of a railway safety education program and the establishment of railway safety education centers as a means of preventing railway accidents.

Peer-review under responsibility of Dept of Transportation Engineering, University of Seoul.

Keywords: railway, railway accidents, railway safety education program, railway safety education center ;

1. Introduction

1.1. Background

As efforts are increasing in order to create an environmentally-friendly urban transportation environment, public transport policies have shifted their focus from a road-centric approach to one that is more rail-centric. This is helping to stimulate an increase in railway usage. However, regardless of this increase in the number of rail passengers, safety measures ensuring passenger safety are still in need of much improvement. In 2010, a significant amount of enhancements and installations of safety equipment led to a sharp drop in the number of railway accidents but this rate of decline has since slowed down.

Railways make up one of the most vital types of infrastructure in society and many of them are now being operated under automated systems, but accidents are still prevalent and are being caused by station equipment, passengers, and employees. In addition to the general transit population, the recent increase in the use of bikes has resulted in an influx of cyclists using rail as well. This has also given rise to an increase in accidents. In addition, a lack of a systematized approach on managing and recording incidents of railway- related accidents as well as an absence of safety education centers further contributed to accidents involving passengers falling off the platform, incidents involving

*Corresponding author. Tel.: +82-42-615-4690 ; Fax: +82-2-361-8541.
E-mail address: urban925@korail.com

Peer-review under responsibility of Dept of Transportation Engineering, University of Seoul.
doi:10.1016/j.sbspro.2016.04.016

being jammed in doors, slipping on stairs, and others. There are also a high number of delays due to malfunctioning trains and rail equipment. Consequently, in order to ensure passenger safety amid the increasing trend of railway use, steps need to be taken to analyze causes of accidents and to reduce the number of accidents. This paper surveys and analyzes the characteristics and underlying causes of urban railway accidents that result in injuries or death. Based on this analysis, this paper proposes measures that can be taken to prevent such railway accidents.

2. Preceding Research

In Classification of Railroad Accident Types and Its Standardization (Lim and Kim, 2006), characteristics of domestic and overseas railway accidents were compared and analyzed as a means to deduce policy implications. By re-categorizing and standardizing different types of railway accidents, the study suggested having standardized railway accident codes and sorting various different railway accidents and maintained that this system is a key element within the railway safety management system.

In Railroad Accident and Emergency Response Management System Report (Kim et al., 2008), preparation of scenarios for different emergency situations in railway operations and development of standardized operation procedures for emergency responses were suggested. Emergency situation scenarios for high-speed rail and conventional rail as well as standardized emergency response procedures were proposed to be included within standard emergency response procedures. It further proposed development of training programs for railway employees and related personnel. In Facilities in Urban Rail Safety Survey Report (Korea Consumer Agency, 2010), passenger-related accidents and urban railway accidents in Seoul and the greater metropolitan area were studied by randomly selecting 26 stations as samples. Focusing the research on types of equipment that were most often found to be involved in accidents, incidents were analyzed so that measures could be taken to prevent passenger accidents. In Building Railroad Accident Risk Analysis and Evaluation System Report (Wang et al., 2011), a standardized categorization model for railway accident risks was suggested. It also suggested the development of a threat evaluation system as well as proposing a test and certification model for railway system safety. It proposed a railway safety management system based on a system involving threat analysis of railway accidents and threat level evaluation. Through such types of implementation, railway safety management in Korea could be brought up to par with those in developed countries and it would be able to better respond to the increasing number of technical and social hazards. Furthermore, in Rail Safety Statistics Report (Ministry of Land, Infrastructure and Transport, 2013), 5 years' worth of information that is available in the railway safety information management system during the years between 2008 and 2013 was analyzed. Analyzed information included accident information on high-speed, conventional, and urban railways. The study revealed the trends in railway accidents and causes of railway accidents for each quarter of the year during the period of study. In Railway Safety Performance Report (Ministry of Land, Infrastructure and Transport, 2013), information from Britain's Rail Safety & Standard Board (RSSB) and Annual Safety Performance Report (ASPR) was used as references for categorizing domestic railway accidents and analyzing threat levels. The study provided information on rail safety to personnel in the railway sector and supplied analytical information on the causes of railway accidents.

Table 1. Comparison of operational characteristics of Urban and Conventional Railways

Category	Operational distance (km)	#of stations	#of trips (per day)	Scheduled speed (km/h)	Transport volume (thousand passengers/ year)	Transport volume (thousand passengers/ day)	Average distances between stations (km)	Average # of passengers per trip (passengers/trip)	Average # of passengers a day per station
Urban Railway	137.9	120	2,423	29.3-35.9	1,513,665	4,136	1.15	1,707	34,467
Conventional Railway	3,052	330	362	65.8-93.7	79,644	219	9.25	605	664

Source : 2014 DB from railway operation organizations

3. Railway accident characteristics and cause analysis

Railway accident characteristics and causes were analyzed using the internal information of rail operators. The analysis studied trends by accident types, age, gender, location of accidents, and characteristics of rail accidents at different times of the day. Types of analyzed information, period covered, and scope of data are described in Table 2.

Table 2. Data Resources of Railway Casualty Accidents

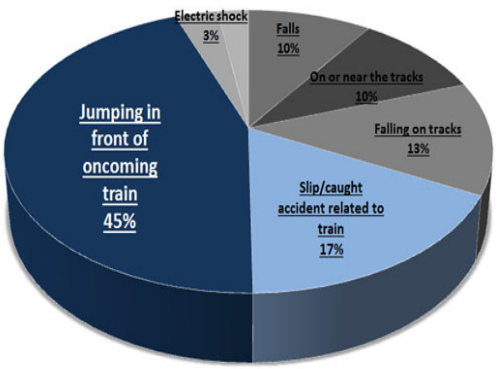
Category	Contents
Data Resources	Accident database from railway operation organizations
Period of Data	A total of 36 months from January 2011 to December 2013

3.1. Analysis of railway accident characteristics according to accident types

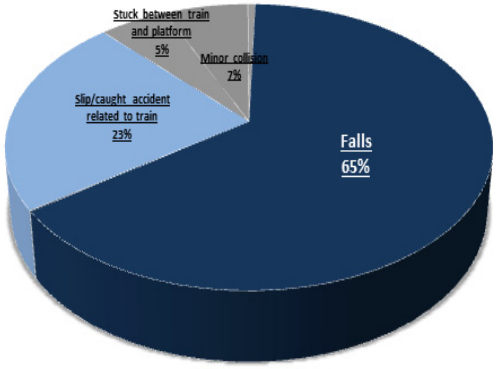
Of the 2,997 railway accidents that occurred between 2011 and 2013, 2,788 were urban railway accidents and 209 were conventional railway accidents.

Conducting a frequency analysis by accident type for both urban railway accidents and conventional railway accidents revealed the following: Urban railway accidents most frequently occurred in the order of falls (65%), train related slip/caught accidents (23%), minor collisions (7%), and becoming stuck between trains and platforms (5%), while conventional railway accidents were most common in the order of jumping in front of oncoming trains (45%), train-related slip/caught accidents (17%), falling on tracks (13%), and being on or near the tracks (10%).

A comparative analysis of accident types showed that for urban railway accidents, accidents were mostly caused by passenger-driven mistakes such as falls, collisions, and becoming stuck between train and platform, whereas conventional railway accidents mostly occurred in relation to external factors such as jumping in front of oncoming trains, falling on tracks, and being on or near tracks. This gap can be explained by the operational differences between conventional railways and urban railways.



Analysis of different types of conventional railway accident characteristics



Analysis of different types of urban railway accident characteristics

Figure 1. Analysis of railway accident characteristics according to accident types

Table 3. Results of characteristic analysis of railway safety accidents according to causes of accident

Category	Trapped in E/V	Caught in E/V, E/S	Falls	On or near the tracks	Falling on tracks	Slip/caught accident related to train	Stuck between train and platform	Jumping in front of oncoming train	Electric shock	Minor collision	Others	Total
Urban Railway	0.0%	0.5%	64.5%	0.0%	0.1%	22.7%	5.3%	0.0%	0.0%	6.6%	0.1%	100.0%
Conventional Railway	0.0%	0.0%	9.6%	10.0%	12.9%	17.2%	0.0%	44.5%	3.3%	0.0%	2.4%	100.0%

3.2. Analysis of railway accident characteristics according to passenger age

Analysis of the age of passengers involved in accidents reveals that victims of railway accidents have a varying age range from infants to people in their 90s. Statistics indicate that victims in their 70s are most common at 20.9%. Those in their 50s amounted to 19.6%, 60s was 18.9%, and 20s was 10.6%. It was found that people in their 50s to 70s were most susceptible to railway accidents compared to other age groups.

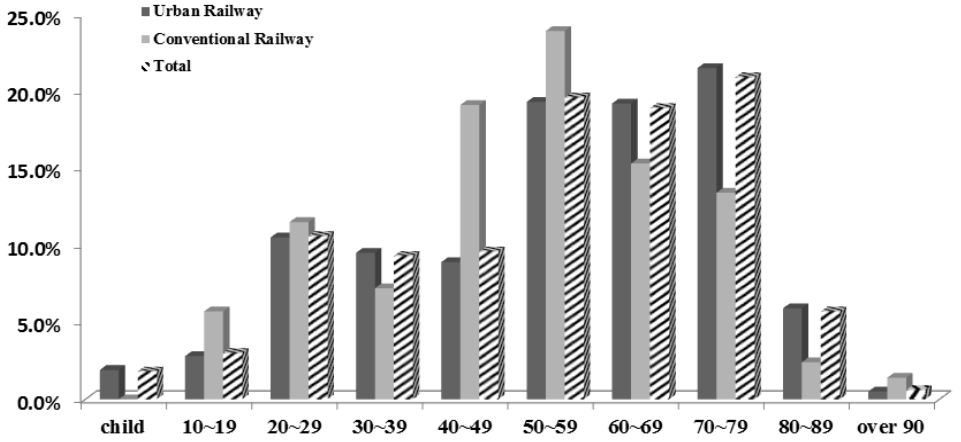


Figure 2. Analysis of railway accident characteristics according to passenger age

3.3. Analysis of railway accident characteristics according to passenger gender

Analysis of the gender of victims involved in railway accidents shows that 51.3% are male and 48.7% are female. In conventional railways, 64.6% were male and 35.4% were female and accidents among males were 5% more likely to occur.

Railway accident analysis according to passenger gender reveals that, excluding accidents within the trains, males were more likely to be involved in accidents than females.

Table 4. Results of analysis of railway safety accidents by gender

	Male	Female	Total
Urban Railway	51.3%	48.7%	100.0%
Conventional Railway	64.6%	35.4%	100.0%
Total	52.3%	47.7%	100.0%

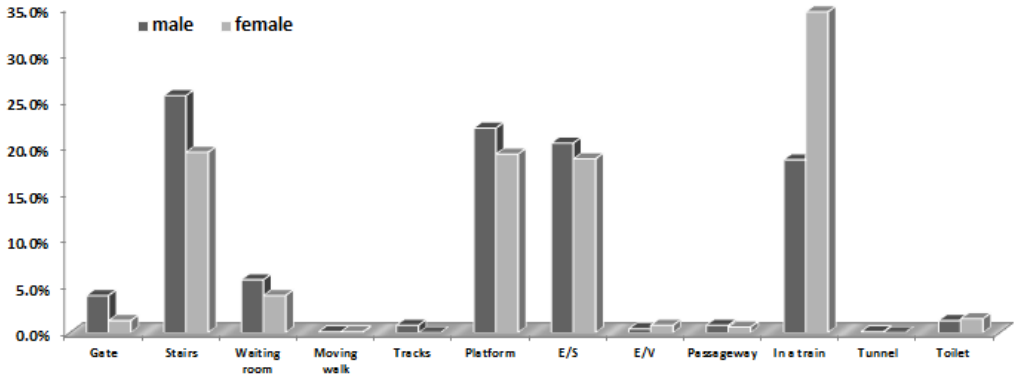
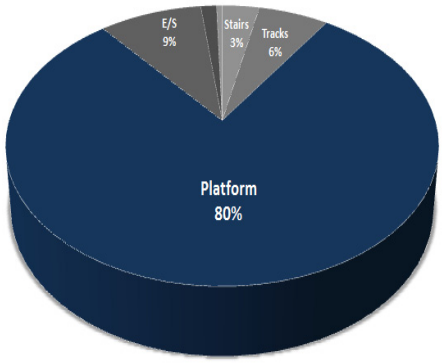


Figure 3. Analysis of railway accident characteristics according to passenger gender

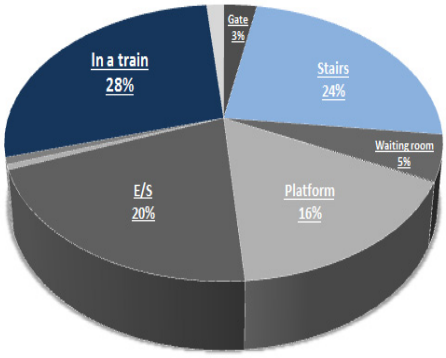
3.4. Analysis of railway accident characteristics according to accident location

Each train station contains a number of main facilities: stairs, gates, waiting rooms, moving walks, tracks, platforms, escalators, elevators, connecting corridors, trains, tunnels, restrooms, etc… This means that railway accidents may occur in any of these places. This section focuses on subtotaling railway accidents for each facility, as well as comparing and analyzing their rate of occurrence.

For conventional railways, 80% of all accidents occurred on the platform, followed by escalators (9%), tracks (6%), and stairs (3%). Urban railway accidents, on the other hand, instead of mainly occurring in one area, had a similar level of frequency in various locations such as trains (28%), stairs (24%), escalators (20%), and platforms (16%). A similar rate of occurrence in multiple locations can be explained by the fact that urban railway has a higher user density, leading to passenger-passenger collisions as well as passenger-facility collisions. As for conventional railway accidents, institutional factors such as low-level platforms and lack of screen doors contribute to higher accident frequency.



Analysis of conventional railway accident characteristics



Analysis of urban railway accident characteristics

Figure 4. Analysis of railway accident characteristics according to accident location

3.5. Analysis of railway accident characteristics according to hours of day

Peak commuting hours (around 8am and 6pm) revealed the highest rate of accidents, accounting for 8%. There were more female victims than male victims. This shows that additional safety measures need to be implemented in order to lower accident rates during rush hour.

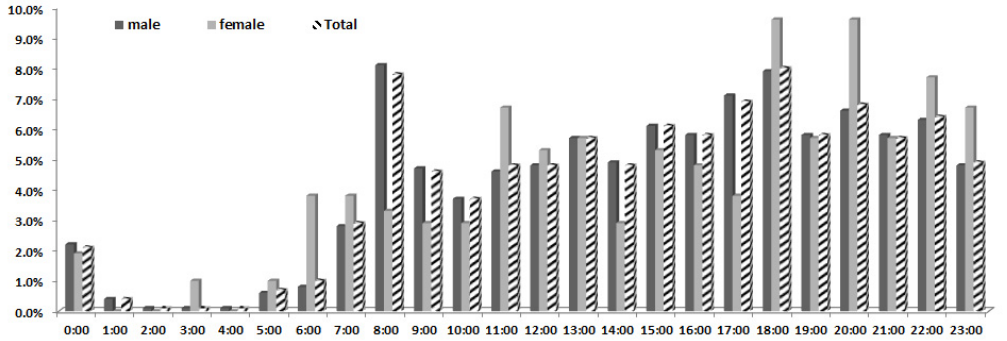


Figure 5. Analysis of railway accident characteristics according to hours of day and gender

3.6. Policy implications

This study attempts to analyze accident characteristics by classifying railway safety accidents into conventional railway accidents and urban railway accidents. Analysis results revealed that, for conventional railways, accidents were most frequently caused by jumping in front of oncoming trains (45%) and the platform was where 80% of all accidents occurred. Among different age groups, people between their 50s and 70s were most susceptible to railway safety accidents, with men getting into more accidents than women.

As for urban railways, accidents were most frequently caused by falls (65%) and occurred most frequently in trains (26%), stairs (23%), platforms (21%), and escalators (20%). People in their 50s to 70s were most susceptible to railway safety accidents, with men having a slightly higher rate of accident (5%) compared to women. Also, while most conventional railway accidents occurred in platforms due to jumping in front of oncoming trains, urban railway accidents occurred in various locations within the station due to falls.

The difference in accident location and cause of accident can be explained by the difference in operation method and facility design for the two types of railways. For conventional railway stations, safety education should be improved, while for urban railway stations, movement flow within the station should be better instructed.

This study mainly proposes three measures to prevent and reduce railway-related accidents. Firstly, railway safety education and awareness promotion programs need to be developed for passengers (manuals, books, and audiovisual contents). Secondly, areas vulnerable to railway accidents need to be isolated and a Safety Diagnosis and Improvement Manual for Railway Stations (tentative title) needs to be developed. Thirdly, railway safety education centers need to be established for different railway types so that people can learn and experience how to protect themselves from the risk of railway accidents.

Through these measures, better prevention and responses against railway accidents can be possible. Also, the level of awareness will be raised regarding railway safety among passengers and rail operators.

4. Establishment of railway accident safety measures

4.1 Development of railway safety education and awareness promotion programs for railway passengers (manuals, books, and audiovisual contents)

This research developed a survey regarding existing safety promotion and education programs currently in place in order to propose more adequate and effective safety education and awareness promotion programs (manuals, books, audiovisual contents) for rail passengers. Research showed that most operators displayed promotional videos, safety rules and other materials, as a means to raise safety awareness. However, it was found that with the exception of Korea Rail Road Corporation and Busan Transportation Corporation, no operator provided safety education programs. Details are shown in Table. 5.

Railway safety education programs are usually conducted in the form of basic videos. This approach cannot be expected to have a high level of effectiveness. Also, since targeted viewers are mostly children and students, it fails to capture the diverse and varied groups of people using the railway. Consequently, this research proposes that railway safety education standard manuals, customized textbooks (students, adults, disabled), e-learning audiovisual contents, and other resources need to be developed so that people can have a better understanding and be able to concentrate on the material being presented. Furthermore, with regard to accidents involving passengers, causes of accidents should be classified in a standardized manner and rail safety technologies also need to be defined. Through an educational program centered on examples of real-life accidents and by providing hands-on educational experiences, passengers will be better equipped to actively avoid and respond to different accident situations. Details are described in Table 6.

Table 5. Urban Railway Safety Manual and Education Program by Railway Operation Company

Category			Urban Railway Operation Company						
	Korail	Seoul Metro	Subway #9	Seoul Urban Railway	Daejeon Urban Railway	Gwangju Urban Railway	Daegu Urban Railway	Incheon Urban Railway	Busan Urban Railway
Subway Safety Guidebook	○	○	○	○	○	○	○	○	○
Railway Excursion Program	○	None					○	○	○
Safety Video	○	○	○	○	○	○	○	○	○
Safety Education Program	○	○	None						○

Table 6. Improvement of Safety Education Programs

Category	Contents
Programs by Pedestrian Group	- A manual or guidebook based on various pedestrian types such as normal adults, the disabled, the elderly, infants, pregnant women, etc…
Customized Safety Contents	- Web accessibility for people with disabilities, such as sign language training programs, Web 2.0 guidelines - Infant / mascot made for elementary students
Focusing on Comprehension	- 3D graphics (hologram), combined with a virtual reality technology education program - Improve concentration by applying the techniques of storytelling
Informative Training Contents	- Training contents according to pedestrian facility (Elevators, escalators, platform, stairs) including near-miss accidents
Various Media	- Use of smartphones, smart devices that transcend the PC environment

4.2 Development of Safety Diagnosis and Improvement Manual for Railway Stations (tentative title)

General railway safety issues must be diagnosed by taking the characteristics of railway stations into account. To diagnose, propose means of improvement, and contribute to more optimized railway safety, a Safety Diagnosis and Improvement Manual for Railway Stations (tentative title) needs to be developed. In the Safety Diagnosis and Improvement Manual for Railway Stations (tentative title), various elements need to be included such as: test items, testing methods and procedures, personnel conducting diagnosis, diagnosis report format, follow-up measures after diagnosis, evaluation standards, and cost calculation methods.

A work flowchart for safety diagnosis of railway stations is shown in Figure 6.

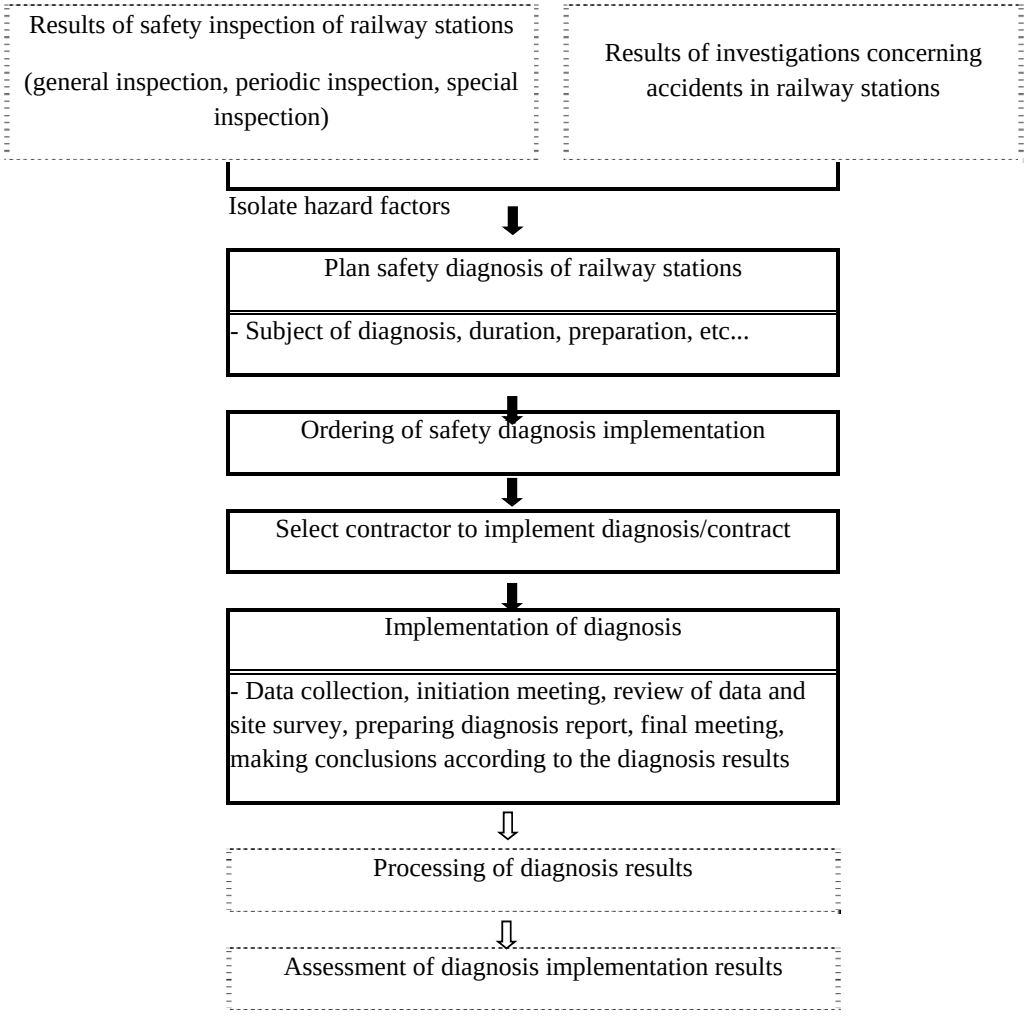


Figure 6. Flow chart of safety diagnosis tasks for railway stations (tentative plan)

4.3 Establishment of railway safety education centers

In order to prevent and adequately respond to railway accidents, advance training and experience are essential and railway safety education centers are needed for this purpose. There have been a few operator-centric safety education centers aimed at providing preventive education but presently, there is no safety education center centered on railways.

Therefore, in order to adequately educate the public of the uniqueness and special characteristics of railways, railway education centers need to be installed in existing idle space within stations or in locations that are home to railway districts. Close cooperation with rail operators is needed so that existing idle spaces can be utilized to reduce costs and ensure the public's ease of access.

Since accidents can happen under any situation, no one is safe from harm. This is why hands-on education and experiences are vital because they can expose people to various different scenarios, while accommodating the special needs of learners. Educational contents should focus on the special characteristics of the railway and should recreate a reality to which the people may potentially be exposed to. Through passenger surveys, on-site investigation, and using other methods, different contents should be prioritized according to their importance. By taking the movement patterns of the passengers into account, safety experience items should be installed to maximize educational experience. Different types of accidents in different stages of passenger movement are shown in Figure 7.

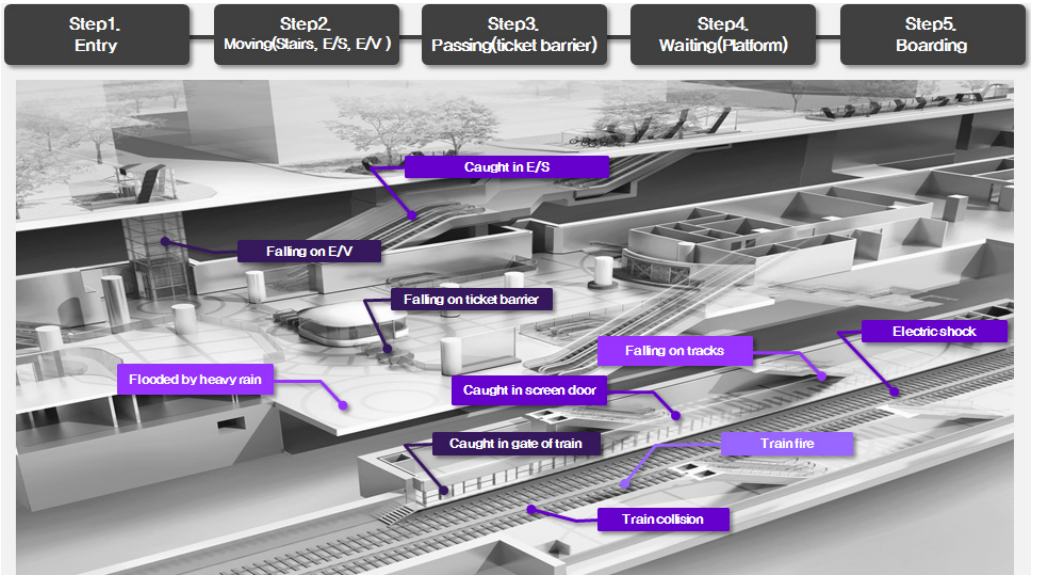


Figure 7. Different types of accidents in different stages of passenger movement

Analyzing the government's future safety and accident prevention policies will aid railway safety education centers to be installed in connection with such policies. By providing highly specialized and hands-on education, the educational effect of railway safety on passengers can be maximized.

5. Conclusion and future research

Railway accident characteristics and causes were analyzed using the internal information of rail operators. The analysis studied trends by accident types, age, gender, location of accidents, and characteristics of rail accidents at different times of the day. Types of analyzed information, period covered, and scope of data are described in Table 2.

This study analyzed databases of railway accidents that were contributed by rail operators. The data was analyzed according to the type of accident, age, gender, location of accident, and time of accident. By analyzing characteristics of railway-related accidents using these factors, methods of prevention were proposed. Firstly, falls (60.7%) accounted for most railway accidents followed by train-related slip/caught accidents (22.4%). With respect to the location of accidents, 26% occurred inside trains, 23% in stairs, 21% on platforms, and 20% on escalators. Among different age groups, people in their 50s to 70s were most susceptible to railway accidents. Measures need to be taken to resolve this issue.

This study mainly proposes three measures which can be taken to prevent and reduce railway accidents. Firstly, railway safety education and awareness promotion programs need to be developed for passengers (manual, books, and audiovisual contents). Secondly, areas vulnerable to railway accidents need to be isolated and a Safety Diagnosis and Improvement Manual for Railway Stations (tentative title) should be developed. Research on railway safety education programs have found that only 1 out of 8 rail operators provided a safety education program, which is not an acceptable number. Inadequate structure of educational contents and limited target groups also mean that it is difficult to expect meaningful educational effects on passengers. In order to maximize the educational effect, this paper proposed that varied groups must be targeted and contents should be tailored to different groups. Also, in order to enhance the learner's understanding and gain their full attention, educational contents should include examples of real-life incidents as well as delivering the material through a range of media utilizing widespread usage of smart devices and electronic devices. Thirdly, railway safety education centers need to be established for different railway types so that people can learn and experience how to protect themselves from railway accidents. Research has shown that railway safety education centers lack a comprehensive educational approach in addition to a lack of utilization of advanced IT technologies which lead to ineffective learning. Therefore, it is crucial to establish safety education that covers all different types of accidents and is provided in connection with on-line educational materials. Furthermore, safety education and hands-on experiences should utilize existing advanced IT technologies. In order to implement railway safety measures proposed in this paper, close cooperation with rail operators is necessary and further research and development is also needed to ensure passenger safety.

In order to obtain data on factors affecting accidents in railway stations and to enhance reliability and accessibility of such data, railway accident databases coupled with an analysis system need to be created. The outcome of this research could provide meaningful direction in its creation.

Acknowledgements

This research was conducted using funding from the Railway Technology Research Project (15RTRP-B067918-03) provided by the Ministry of Land, Infrastructure, and Transport of Korea.

References

Korea Consumer Agency (2010). Facilities in Urban Rail Safety Survey Report (in Korean)

Lim, K. K., Kim, S. G., (2006). “The Classification of Railroad Accident Types and Its Standardization” Journal of the Korean Society of Civil Engineers, Vol. 26, No. 1D, pp. 133-135 (in Korean).

Ministry of Land, Infrastructure and Transport (2013). Rail Safety Statistics Report (in Korean)

Ministry of Land, Infrastructure and Transport (2013).Railway Safety Performance Report (in Korean)

Ministry of Land, Transport and Maritime Affairs (2011). Building Railroad Accident Risk Analysis and Evaluation System Report, No. 04-Rail Safety-C01 (in-Korean)

Ministry of Land, Transport and Maritime Affairs (2008). Railroad Accident and Emergency Response Management System Report, No. 04-Rail Safety-B04 (in-Korean)

Ministry of Security and Public Administration (2014). National Safety Management Plan (in Korean)

Park, Seok-jin (2007). A Study on Efficient Methods of Installation and Operation of Experiential Education Facilities for Public Safety with focus on Experiential Education of Fire Safety (in Korean)

Yang, Meong-sik (2011). A Study on The Safety Experience Museum Plan based on The Experience Programs and Cases Analysis (in Korean)