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Analysis of Emergency Response to Urban Rail Transit Incidents

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Abstract

The safe operation of urban rail transit is closely related to the lives and property of the people and the harmony and stability of the social environment. The handling of urban rail transit emergencies is particularly important. This paper classifies urban rail transit emergencies based on their nature and occurrence mechanism, elaborates on their characteristics, analyzes the problems existing in the emergency response of urban rail transit, and proposes emergency management measures for urban rail transit. By establishing and improving the emergency response system, the emergency response capabilities and handling efficiency of urban rail transit operation units can be enhanced, ensuring the restoration of normal operations in the shortest time and maintaining the smoothness of urban transportation.

Subject Areas

Economics

Keywords

Urban Rail Transit, Emergencies, Emergency Response Measures

1. Introduction

Urban rail transit provides fast and convenient transportation services for urban residents and has become an indispensable mode of transportation for them. With its advantages such as high comfort, high punctuality, high safety, and energy conservation and environmental protection, it has gradually become the main artery of urban public transportation. It plays an important role in alleviating urban traffic pressure and improving the efficiency of residents' travel. As a large-scale public transportation facility, urban rail transit has a large passenger volume, high personnel density, relatively closed space and is located underground. These char-

acteristics also mean that once an emergency occurs in urban rail transit, if it cannot be controlled in a targeted manner and rescue cannot be carried out effectively and quickly, it will bring unpredictable losses to the lives and property of passengers and society. Therefore, urban rail transit has higher requirements for the handling, rescue and evacuation of emergencies. Only by giving full play to the role of the emergency response system can emergencies be resolved in a timely and effective manner, and the adverse effects caused by emergencies be minimized [1].

2. Classification of Common Accidents in Urban Rail Transit

Urban rail transit emergencies refer to sudden occurrences of natural disasters, accident disasters, public security incidents, social security incidents, etc. in subway operation sites. The causes of these accidents are diverse [2]. Factors such as harsh natural environments, equipment failures, and improper human operations can all lead to accidents, resulting in casualties, property losses, negative public opinions, and affecting the safety of train operations, causing adverse impacts on society. Common classifications of urban rail transit emergencies are as follows.

2.1. Natural Disasters

Natural disaster accidents in urban rail transit mainly include incidents caused by severe weather or unexpected events such as strong typhoons, tornadoes, floods, earthquakes, landslides, and thunderstorms, which lead to urban rail transit being flooded, derailed, overturned, etc., affecting the normal operation of rail transit, causing train operation disruptions, facility damage, and even casualties. Such incidents are usually classified as "force majeure events", which are distinct from liability accidents caused by human negligence, technical malfunctions or inadequate safety management. For instance, the 2004 Sri Lanka tsunami overturned a train, resulting in severe casualties and property losses.

The impact of natural disasters on urban rail transit is mainly reflected in the following aspects: First, it damages rail transit facilities and equipment, such as track deformation, bridge collapse, power supply interruption, and signal failure, which makes it impossible for trains to operate normally; second, it triggers secondary disasters, such as mudslides caused by floods may bury stations and tracks, and fires triggered by earthquakes may cause even greater damage to stations and trains; third, it affects the safety of passengers, such as flooding of stations and trains may lead to drowning of passengers, and building collapses may cause casualties.

2.2. Accidents and Disasters

Accidents and disasters in urban rail transit mainly include fires, explosions, large-scale power outages, equipment failures, and sudden surges in passenger flow, which affect the normal operation of urban rail transit. For instance, in 2013, a large-scale power outage occurred in Shanghai, causing disruptions to the operation of Shanghai Metro Line 2 and trapping many passengers in the subway for over 40 minutes. In 2012, a fire broke out in a carriage of Guangzhou Metro Line

8, leading to a mass evacuation of passengers through the tunnel. During holidays and large-scale events, a sudden accumulation of passengers at subway stations can cause congestion, making stampede incidents highly likely and posing serious safety risks [3].

The impact of accidents and disasters on urban rail transit is mainly reflected in the following aspects: Firstly, they directly threaten the lives and safety of passengers, such as fires and explosions which may cause casualties, and train derailments and collisions which may result in injuries to passengers inside the carriages. Secondly, they cause traffic disruptions, affecting the normal operation of the city, such as equipment failures and large-scale power outages which may lead to train suspensions, impacting passengers' travel and the city's economic activities. Thirdly, they bring huge economic losses to rail transit operating companies, such as the need for substantial funds to repair damaged facilities and equipment, and increased operational costs due to accident handling and compensation.

2.3. Public Health Incidents

Public health incidents in urban rail transit mainly include major epidemics, toxic gas, radioactive contamination, etc., which affect passengers' health and threaten their lives and safety. For example, during the outbreak of the COVID-19 pandemic, due to the large passenger flow, high density of people, and relatively enclosed operation of urban rail transit, the virus was prone to spread, thus urban rail transit was significantly affected, with passenger flow remaining low for a long time. Many operating companies suspended operations, while those that did not also formulated corresponding emergency response plans and actively carried out epidemic prevention work to create a safe and pleasant travel environment and deal with the impact of the epidemic. In 2020, the COVID-19 pandemic broke out globally, posing unprecedented challenges to the operation of urban rail transit. During the epidemic, due to the large passenger flow, high density of people, and relatively enclosed space of urban rail transit, the risk of virus transmission was high [4]. To prevent and control the epidemic, urban rail transit operating units in various places took a series of measures, such as strengthening ventilation and disinfection in stations and trains, requiring passengers to wear masks, taking temperatures, and limiting passenger flow. Although these measures effectively curbed the spread of the epidemic to a certain extent, they also led to a significant decline in passenger flow and increased operational costs, imposing huge economic pressure on operating companies.

The impact of public health incidents on urban rail transit is mainly reflected in the following aspects: Firstly, they threaten passengers' health and safety, such as major epidemic situations which may cause passengers to contract diseases. Secondly, they affect the normal operation of rail transit, such as measures like limiting passenger flow and suspending operations taken to prevent and control the epidemic which may affect passengers' travel. Thirdly, they bring economic losses to operating companies, such as increased operational costs due to en-

hanced ventilation and disinfection and the purchase of epidemic prevention materials, and reduced revenue due to decreased passenger flow.

2.4. Social Security Incidents

Social security incidents in urban rail transit mainly include mass disturbances and terrorist attacks, which are highly sudden and have a significant impact on passenger safety and operational services. For instance, in 2002, the Daegu subway arson case in South Korea resulted in 98 deaths and 147 injuries. In 2024, a knife attack occurred at the Hechuan Road Station of Shanghai Metro Line 9, causing three injuries. Although the incident happened outside the security checkpoint, such violent cases also test the emergency response capabilities of station staff. If not handled properly, the consequences could be unimaginable.

The impact of social security incidents on urban rail transit is mainly reflected in the following aspects: Firstly, they directly threaten the lives and safety of passengers, such as terrorist attacks and sudden illnesses of passengers which may cause casualties. Second, it can cause traffic disruptions and social panic. For instance, mass disturbances may lead to disorder at stations, affecting the normal operation of trains and triggering social panic. Third, it can have a negative impact on the image and reputation of urban rail transit. For example, the occurrence of vicious incidents can reduce public trust in rail transit [5].

3. Characteristics of Urban Rail Transit Accidents

3.1. Strong Suddenness

The long and narrow lines, enclosed spaces, dense passenger flow, and the coordinated operation of multiple devices in urban rail transit all contribute to the strong suddenness of accidents. Emergencies often occur in a very short time, with highly uncertain occurrence times and locations. The initial manifestations of the accident are very subtle and difficult to detect. They occur suddenly and, once they occur, they can rapidly develop into large-scale incidents with a certain degree of harm, possibly causing panic and chaos among passengers, and even resulting in casualties and severe property losses [6].

3.2. Strong Urgency

Urban rail transit is densely populated, has a complex system, and numerous potential risks. Once an emergency occurs, it will have a certain impact range [7]. Any link may trigger a chain reaction, expanding the scale of the accident and posing a serious threat to public safety. Therefore, emergency response must be prompt to avoid severe losses. Only by ensuring that rescue work can be carried out in an orderly and rapid manner when an accident occurs can the number of casualties and property losses be minimized.

3.3. Large Social Impact

Emergencies may lead to traffic disruptions and affect residents' travel. As urban

rail transit involves the lives and property of numerous passengers, it will quickly draw public attention and have a direct impact on the image of enterprises, the image of the city, and the trust of the government. It may also trigger public opinion, damage the image of rail transit enterprises, affect their economic benefits and social reputation, and in more severe cases, cause public panic and bring instability to society, affecting social stability.

3.4. High Difficulty in Disposal

The factors that trigger emergencies are complex and diverse. Correct judgments must be made during disposal. Moreover, urban rail transit is in a closed or semi-closed state, with a dense and highly mobile population and few escape routes, making safe evacuation difficult. Professional guidance and active passenger cooperation are required, along with good coordination. Additionally, urban rail transit operations involve multiple departments, such as operation command, civil engineering, signaling, power supply, and train control. Coordination among multiple departments is necessary, making management complex and command coordination difficult.

4. Analysis of Problems in Urban Rail Transit Emergency Response

Although China has achieved certain results in urban rail transit emergency management, there are still some problems in actual operation that need to be further improved and perfected. These problems mainly lie in the incomplete emergency response system, ineffective emergency drills, the need to improve the professional skills of personnel, the lack of emergency awareness among passengers, and insufficient emergency rescue resources.

4.1. Incomplete Emergency Response System

Emergency plans are the important basis for emergency response. However, some emergency plans for urban rail transit currently have issues such as being impractical, lacking scientificity and operability. Some emergency plans are too general, with insufficient classification and grading of emergencies, making it difficult to accurately determine the nature and severity of the incident during actual emergency response and hindering the prompt adoption of effective measures. Some emergency plans have unclear division of responsibilities among departments, leading to overlapping and blank areas of responsibility, which may result in buck-passing and poor coordination during emergency response. Some emergency plans lack coordination with other related emergency plans, such as urban comprehensive emergency plans and public security and fire emergency plans, making it difficult to achieve multi-department collaboration during emergencies and affecting the efficiency and effectiveness of emergency response.

There are also some deficiencies in the emergency command and coordination mechanism. When emergencies occur, involving multiple departments and units,

an efficient emergency command and coordination mechanism should be established to ensure that all departments can respond promptly and work together. However, the emergency command and coordination mechanisms in some cities' rail transit systems are still not perfect, with problems such as poor information transmission and delayed decision-making.

1) In some emergency incidents, due to poor information communication among various departments, the understanding of the situation is incomplete, which affects the accuracy and timeliness of command and decision-making. The decision-making process of some emergency command institutions is cumbersome, with too many approval procedures, resulting in a slow emergency response and missing the best rescue opportunity.

2) Poor Effectiveness of Emergency Drills

Emergency drills are an important means to test emergency plans and improve emergency response capabilities. However, in some urban rail transit systems, there is a tendency to focus more on the "performance" rather than the "practice" of emergency drills. The drills are often formalistic, lacking authenticity and practicality. Some drills are conducted strictly according to pre-determined scripts, without considering the randomness and complexity of emergencies, thus failing to truly test emergency response capabilities. During the drills, some participants do not take them seriously and have a perfunctory attitude, not paying attention to every detail, which greatly reduces the effectiveness of the drills.

The evaluation and feedback mechanism for emergency drills is also not well established. After the drills, some units do not conduct in-depth evaluations and analyses of the drill results, failing to promptly identify problems and shortcomings and formulate effective improvement measures. Some units, although they conduct evaluations, only focus on the process and results of the drills, neglecting the assessment of the emergency response capabilities and teamwork of the participants. Due to the lack of an effective evaluation and feedback mechanism, emergency drills cannot play their due role, and the emergency response capabilities cannot be effectively enhanced.

4.2. Professional Competence of Staff Needs Improvement

Urban rail transit operation involves multiple professional fields, and staff are required to have high professional knowledge and skills. However, currently, some staff members lack sufficient professional knowledge and are not familiar with emergency response procedures and methods. When emergencies occur, they cannot make correct judgments and handle the situation promptly. Some train drivers are not proficient in emergency handling methods for train malfunctions and cannot take effective measures in time when encountering sudden faults, leading to the expansion of the impact. Some station staff are not familiar with the emergency response procedures for passenger illnesses and cannot provide effective assistance to passengers in the first instance.

The emergency response capabilities of staff also need to be improved. In emer-

gencies, staff need to have good psychological quality, adaptability, and teamwork skills. However, currently, some staff members tend to become nervous and panicked when facing emergencies, unable to keep a cool head and make correct decisions. Some staff members lack adaptability and cannot respond flexibly and adjust the emergency response plan in time when encountering unexpected situations. Some staff members have weak teamwork skills and cannot cooperate closely with other departments and personnel during emergency response, affecting the efficiency and effectiveness of the response.

4.3. Passengers' Emergency Awareness Is Weak

Passengers are the main users of urban rail transit, and their emergency awareness and self-rescue and mutual rescue capabilities are crucial for responding to emergencies. However, currently, some passengers have insufficient knowledge of rail transit safety and are not familiar with the usage methods of emergency equipment. When emergencies occur, they lack the ability to self-rescue and help others. Some passengers do not know how to use fire extinguishers, emergency braking devices, etc. correctly and cannot take effective self-rescue measures when encountering fires or train malfunctions. Some passengers do not abide by safety regulations in stations and trains, such as touching equipment randomly or playing near the platform edge, which can easily lead to safety accidents.

In addition, some passengers lack the ability to respond calmly in emergencies and tend to panic and become chaotic, which affects the smooth progress of emergency response work. In some emergencies such as fires and explosions, due to passengers' panic, evacuation routes get blocked, which slows down the speed of evacuation and increases the risk of casualties.

5. Emergency Management Measures for Urban Rail Transit

5.1. Establishing an Emergency Response System for Urban Rail Transit to Enhance the Efficiency of Solving Emergencies

The emergency response system for urban rail transit should first start from the institutional level, improving the three-level emergency plan system of comprehensive emergency plans, specialized emergency plans, and on-site response plans, clarifying the responsibilities of each department, and involving experts from relevant fields in the formulation and evaluation of emergency plans to provide technical support and decision-making suggestions [8]. Secondly, information sharing should be strengthened, and an efficient emergency command and multi-department coordination mechanism should be established to form a unified command and coordinated emergency management system. The urban rail transit operation authority is the decision-making body for emergency response. In daily work, the first person in charge should be clearly defined, responsible for organizing and supervising emergency drills for sudden incidents within the operation area, and coordinating the cooperation and linkage among various departments. The daily operation of urban rail transit involves multiple departments and systems such as

operation command, civil engineering, signaling, power supply, and train control. Only with timely and smooth communication, effective and shared information, and the ability to collaborate can the emergency response be swift and efficient when an incident occurs, ensuring that each department can perform its duties promptly and carry out rescue operations, thereby improving the emergency response speed and rescue efficiency.In addition, it is necessary to ensure a smooth connection with other relevant emergency response plans such as the comprehensive emergency response plan for the city and the emergency response plan for public security and fire control, and establish a joint command organization.

5.2. Establishing an Emergency Drill Mechanism to Enhance Emergency Response Capabilities

Emergency drills for urban rail transit are an important means to improve emergency response and handling capabilities. Firstly, emergency drills should be conducted regularly. The drill content should cover various emergencies that may occur during rail transit operations, such as large passenger flows, equipment failures, fires, and train collisions. The drill process should include multiple stages such as incident occurrence, emergency response, information reporting, emergency rescue, and resumption of operations. For specific locations, positions, and emergency scenarios, the handling procedures, operational steps, and precautions for response personnel should be clearly defined. Regular drills not only test the operability and effectiveness of emergency plans in actual operations, identify deficiencies in the plans, but also smooth out the collaboration mechanisms among multiple departments and units, ensuring efficient and rapid cross-departmental cooperation in the event of an emergency. Secondly, emergency drills should be conducted without prior notice of the specific time, assembly of the drill team, preparation of scripts, or synthesis of the drill to ensure the authenticity and urgency of the drills. This can identify problems in the operations of relevant departments and personnel and make improvements, ensuring that the emergency plan can be promptly activated and effective rescue actions can be taken in real emergencies.

5.3. Strengthening Professional Training for Staff and Enhancing Their Professional Qualities

The professionalism of staff directly affects the safety of operation and the travel experience of passengers, especially when encountering emergencies. The ability to resolve crises and handle them effectively and promptly depends crucially on the professional qualities of the staff. On the one hand, regular systematic theoretical and practical training should be provided, and personalized training programs tailored for staff through cloud training and big data. This will continuously enhance their professional qualities, improve their emergency response capabilities, and boost their professional skills. On the other hand, activities such as evaluating online learning hours, awarding excellence in theoretical knowledge, and holding practical skills competitions should be organized to honor the advanced

individuals, increase the fun of learning, and stimulate the staff's interest in learning. Only when they are actively and voluntarily involved in training can they provide better services to passengers.

5.4. Conducting Extensive Emergency Education and Publicity to Enhance Passenger Participation

Passengers are important participants in the emergency management of urban rail transit. On the one hand, warning educational videos and classic accident cases should be played on metro PIS screens and official accounts to raise passengers' safety awareness, improve their understanding and response capabilities to emergency situations in urban rail transit, and strengthen the publicity of emergency knowledge and practical skills, including how to perform CPR and how to use emergency equipment correctly, to enhance their self-rescue and mutual rescue abilities in emergencies. On the other hand, an effective communication mechanism should be established with passengers, and relevant information should be promptly released to passengers through official accounts, Weibo, and websites to enhance communication with passengers, increase their trust and support, and thereby improve the safety level of rail transit and ensure the safety of people's lives and property.

5.5. Establishing Rescue Reserve Teams to Enhance Emergency Rescue Speed

The urban rail transit operation authorities should establish dedicated rescue teams in collaboration with public security, fire, medical, and engineering rescue institutions, and establish an emergency rescue linkage mechanism to achieve multi-unit coordinated rescue. Staff of urban rail transit, as the first responders on the scene in emergencies, should possess professional rescue knowledge and be reserved as part-time teams. As a reserve for part-time teams, professional training is provided in areas such as emergency evacuation guidance, train demolition, initial fire suppression, confined space rescue, emergency communication, and multi-departmental collaborative response. They should be able to quickly reach the scene and efficiently handle emergencies to prevent the expansion of accidents. The establishment of rescue reserve teams can enhance the speed and efficiency of emergency response and the emergency rescue capabilities of rail transit, ensuring the safety of passengers' lives and property.

5.6. Building an Intelligent Early Warning System to Strengthen the Emergency Defense Line for Rail Transit

As the "major artery" of urban operation, the safe operation of rail transit is of vital importance. To do a good job in emergency prediction and prevention, it is necessary to take the control of risk sources as the core, integrate Internet of Things, big data and artificial intelligence technologies, and establish an intelligent monitoring and early warning system covering multiple dimensions such as equipment status, passenger flow changes and meteorological disasters. Through

regular hidden danger investigation, dynamic risk assessment and hierarchical early warning response mechanisms, early identification, early warning and early handling of emergencies can be achieved. At the same time, we should strengthen cross-departmental collaboration and practical emergency drills, enhance the rapid response capabilities of frontline personnel, promote the transformation of emergency management from "passive response" to "active prevention", and effectively ensure the safety of passengers' lives and property as well as the efficient operation of urban traffic.

6. Conclusion

The safe operation of urban rail transit is closely related to the lives and property of a large number of passengers. By establishing an emergency response system for urban rail transit, conducting regular maintenance of equipment, providing professional training, conducting emergency drills, and widely promoting emergency education, the professional quality of personnel can be effectively enhanced, the guarantee effect of equipment and facilities can be improved, the emergency response capabilities of citizens can be strengthened, the collaborative ability of multiple departments in handling emergencies can be enhanced, and the efficiency of emergency response for urban rail transit can be improved. This ensures that in the event of an emergency, a prompt, orderly and effective response can be made, minimizing the losses caused by the accident and reducing the impact of emergencies on passengers and staff to the greatest extent, thus ensuring the safety and orderly operation of urban rail transit.

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Conflicts of Interest

The authors declare no conflicts of interest.

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