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Underground railway safety analysis and planning strategy: a case of Harbin metro line 1, China

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\textbf{Abstract}

With the development of rapid urbanization, the urban expansion and traffic jams are the serious problem of city development. Underground railway plays an important role in urban public transport, which helps to ease traffic congestion. Because of the frequent accidents of underground railway, the research of underground railway safety and the planning strategies lays the foundation for the urban public safety research. This paper reveals the safety situation of Harbin Metro Line 1 in China from the passenger safety consciousness, equipment and environment, and management factors, through a series of subjective questionnaire surveys. However, the reliability and validity of the questionnaire survey are calculated by SPSS 22 software, and used to assess the qualities of investigation results. With the results, the safety problems and the pertinence planning strategies are put forward for Harbin Metro Line 1. The research has a reference value for underground railway planning and construction, and plays a foundation for improving urban public safety.

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\textbf{Keywords:} Underground railway safety, Planning Strategy, Questionnaire surveys, Harbin Metro Line 1, China.

\textbf{1. Introduction}

With the rapid development of urbanization, the problems of urban sprawl and worse ecological environment are serious. The development of underground space is one of the key means to solve the problem of urban capacity...
expansion, and the effective mode to enhance urban functions, improve the urban environment, and save intensive land use. Urban public traffic safety is an important content of ensuring the city security. And the underground railway that it is efficient fast and alleviate traffic, as one part of urban public traffic, leads to frequency public safety accident because of the characteristic of sealing ability and liquidity. Since 2009, there are more than 100 underground railway safety accidents domestic and overseas, including fire, shutdown, crowded stampede, terrorist attacks[1]. The underground railway hidden danger, safety management and passanger safety awareness gradually caught attentions.

According to the related literature, the research of urban railway safety focused on the safety accident analysis, the safety influencing factors analysis, the safety risk assessment, and the safety management and warning. The subway systems are vulnerable to any number of nature and man-made hazards. Besides these vulnerabilities, subways may also be associated with a range of health and safety hazards that could affect both passengers and transit workers, included physical, biological, chemical, electro-magnetic radiation, psychosocial, and the threat of terrorism[2-4]. The safety influencing factors refer to natural, social, and political, economic, cultural and so on [5-7], and the equipment operation and management is the important factor [8, 9]. There are lots of research on safety risk assessment with the methods of qualitative and quantitative analysis, such as questionnaire method[10, 11], Fault Tree Analysis[1, 4], Fuzzy Mathematics method[12-14], Gray Correlation method[15, 16], AHP[17], and Neural network model. Among these methods, questionnaire method combined with other methods is the main study method for the safety risk assessment. To perfect the underground safety management and warning system is the important measures of urban public security improvements that is the common goal of related research. The researches show that the main strategies are including strengthen the awareness of public safety, improving the hardware and facilities construction, enhancing the underground railway safety maintenance [18, 19].

This paper aims to examine the underground railway safety of Harbin metro line 1 in China based on a series of field experiments and questionnaire surveys, including the passenger safety consciousness, equipment and environment, and management factors. And the current problems of underground railway safety of Harbin are analysed, and the statgies are put forward for underground railway construction and management to improving safety.

2. Methodology

2.1. The area and objective

The subjective survey mainly focused on the public and the underground railway staff. Questionnaires were distributed to 18 stations of Harbin metro line 1, as shown in Fig. 1. The passangers were randomly selected, and it was ensured that there were more than 20 valid questionnaires from each stations, and that the survey sample is representative.
2.2. Questionnaire survey

The purpose of questionnaire design is to study the current problems and the factors of underground railway safety. Based on results of related research on the underground railway safety[10, 15, 20], the questionnaire includes:

- Basic information of the interviewee;
- Experience and safety awareness of interviewee;
- Space and facilities of underground railway;
- Management and services of staff.

3. Results

3.1. The reliability and validity analysis of Questionnaire survey

The questionnaires are analysed using SPSS 22 software and a reliability test was conducted using the Cronbach α parameter on relations mind-body growth rate, overall the safety awareness, the space and the management of the underground railway. Through the 20 items data of questionnaire, the Cronbach α is 0.825 which is greater than 0.7, and KMO is greater than 0.7 which significance is 0.000. The data shows that the reliability and validity of the questionnaire can be accepted (Tab.1).

<table>
<thead>
<tr>
<th>Index validation items</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability test</td>
<td></td>
</tr>
<tr>
<td>Cronbach α</td>
<td>0.855</td>
</tr>
<tr>
<td>Str. Cronbach α</td>
<td>0.969</td>
</tr>
<tr>
<td>Sig.</td>
<td>.000</td>
</tr>
<tr>
<td>Validity test</td>
<td></td>
</tr>
<tr>
<td>Kaiser-Meyer-Oklin (KMO)</td>
<td>0.705</td>
</tr>
<tr>
<td>Bartlett’s spherical verification Approximate chi-square distribution</td>
<td>107.505</td>
</tr>
<tr>
<td>Degree of freedom</td>
<td>20</td>
</tr>
<tr>
<td>Sig.</td>
<td>.000</td>
</tr>
</tbody>
</table>

3.2. Overall situation of Harbin Metro Line 1

Harbin metro is the Chinese first alpine subway, and the urban underground rail traffic lines with the highest latitude. It officially started construction from September in 2008, completed construction at the end of 2012, and formally opened in September of 2013. The whole line across a total 18 station, 17.47km long.

During the survey, in total 360 questionnaires were distributed, with 345 as valid, including 131 males and 214 females. There were 307 publics and 38 staffs, a ratio proportional to that nationwide figures. The age 21~40 passengers accounted for 75% of all investigators, which is most of young. And they have quick reaction speed, the strong ability of perception and observation to help them respond to the emergency.

The basic information of interviewee as shown in Fig. 2a, 2b and 2c. The frequency and the purpose of the interviewee are shown in Fig. 2d and 2e.
3.3. The factors analysis of subway safety

3.3.1. Passenger safety consciousness

83% of the passengers are concerned about the security situation in Harbin metro (Fig. 3a). According to the statistics, 80% of the passengers have not experienced unsafe events in underground railway. And there are a half of the experienced passengers encountered theft (Fig. 3b). When the fire, power outages, explosions, terrorist attacks and other emergencies are occurred in the underground railway, some passengers do not know how to do and do not calmly handle emergencies (Fig. 3c).
3.3.2. Environment and Equipment

Space.

The statistics data shows that the ticket entrance and the escalator are crowded (Fig.4 and Fig. 5a~c). This paper selected 6 typical sites, including 3 types of hospitals, universities, and business sites. Though the investigate, there are a lot of people flow on morning peak(7:00-9:00) and evening peak(17:00-19:00) (Tab. 2).

Table 2. The people flow of morning peak and evening peak.

<table>
<thead>
<tr>
<th>Station Time</th>
<th>The 2nd Affiliated Hospital of HMU</th>
<th>Heilongjiang University</th>
<th>Xuefu Road</th>
<th>HIT</th>
<th>Musume</th>
<th>Harbin Engineering University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ticket Entrance</td>
<td>1/4</td>
<td>2/3</td>
<td>3A/3B</td>
<td>1/3</td>
<td>1/3</td>
<td>1/2</td>
</tr>
<tr>
<td>Morning peak(7:00-9:00)</td>
<td>892</td>
<td>358</td>
<td>394</td>
<td>620</td>
<td>864</td>
<td>592</td>
</tr>
<tr>
<td>Evening peak(17:00-19:00)</td>
<td>1105</td>
<td>422</td>
<td>259</td>
<td>426</td>
<td>416</td>
<td>365</td>
</tr>
</tbody>
</table>

Safety signs

The safety signs in the underground railway included safety channel, safety warning and yellow safety line. Most of passengers have good understanding of the yellow safety line, but they have no understanding of other safety signs (Fig. 6). In addition, more than half of the passengers do not know the location of the passenger safety tips (Fig. 7).
Safety facilities.

The investigate data shows that the passengers know the location and usage of the common emergency facilities, such as fire extinguishers and escape hammer. But for the emergency alarm device, the escalator stop device and the emergency door knob, most passengers do not know where it is and how to use it (Fig. 8a). And 51% passengers can not use the escalator correctly and have no fixed standing habits (Fig. 8b), which will result in unsafe accidents on the escalator. More than 80% of the passengers will notice the close bell and actively cooperate with the safety check, which can ensure the safe operation of underground railway.

3.3.3. Management

Safety propaganda
The main stage of the public security information are the internet and the TV news. And 60% of the passengers hope to get the underground railway safety information through the safety manual and the electronic bulletin (Fig. 9a). But the electronic bulletins are the commercial advertising, and the propaganda shelves are empty (Fig. 9b).

Safety management.
With the statistical data, the factors of improving safety risks are the public awareness of safety, the security facilities and the management efficiency. Most of passengers think that the staff need to improve the safety guiding, including “call for getting down before up”, “safety guidelines entrance direction”, “point passenger misconduct”, and “take care of things”. In addition, the underground railway construction and management need be strengthened and improved, including emergency equipment demonstrations, emergency first aid measures, emergency accident exercises, safety signs strengthening, and safety personnel patrol.

4. Conclusion and Discussion
This paper analyzes the safety situation of Harbin Metro Line 1 in China from the passenger safety consciousness, equipment and environment, and management factors based on the combined approaches of the questionnaire surveys, the field research and the statistical analysis. The results reveals that, (1) the citizens have “short board” on underground railway safety knowledge, and they can not calmly deal with unexpected accidents; (2) the safety facilities are complete in the Harbin Metro Line 1, but most passengers do not know the location and the usage of these facilities; (3) the source of safety information is simple, and there is less propaganda and the lack of emergency accident exercises. In summary, Harbin underground railway safety issues focuses on public safety awareness and safety management. Therefore, there are 2 aspects to improve the underground railway safety situation, including improving the public safety awareness and strengthening the subway security management.

First, for the passengers, the core strategies are strengthening the public safety travelling education and improving the emergency response capabilities for dealing with emergencies. The passengers should be actively involved in safety lectures organized by the corporation, and learn how to properly use emergency facilities and how to escape and self-help during the emergency accidents. Second, the staffs should emphasis on the education of legal, technical and safety management. The sense of responsibility of staff should be enhanced for safety management, and “safety first” operating guidelines should be remembered. And the safety manual and the electronic bulletin should be fully utilized for propagandaoing the fire safety and first aid measures. What’s more, comprehensive coordination mechanisms of the underground railway safety can be effectively established for ensuring the safe operation of underground railway and preventing the occurrence of accidents.
References


