Simulation of Emergency Evacuation in a metro-rail transit station

Akter Gulaur1, Cheng Tian1, Qing Xie1, Hosen Md. Shawkat1, Dong Liu1

1School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing, 400065, China
*Corresponding author’s e-mail: xieqing@cqupt.edu.cn;cqupttiancheng@163.com

Abstract: As a multi-layered transportation system, the evacuation of metro-rail station is directly related to the safety of people, how to effectively prevent and reduce casualties in emergency situations has attracted more and more attention. In this paper, the authors use Anylogic software to model the Chongqing Daping metro-station and simulate the emergency evacuation of the station in case of fire, the simulation results show that the emergency evacuation time of the station is about 3 min 6s, which means this station meets the requirement of China's subway track design standards. The research of this paper can provide scientific basis and reference for emergency evacuation evaluation of multi-layered transportation system.

1. Introduction
The metro systems plays an important role in guiding the change of urban spatial structure, economic circulation, lifestyle and management mechanism, which is conducive to the integration and development of urban spatial structure and enhance the comprehensive competitiveness of urban areas. As of December 2018, 178 cities [1] in 56 countries around the world host the approximately 180 metro systems. In China alone there have been more than 50 metro lines in 12 cities such as Beijing, Shanghai, Guangzhou, Tianjin, Dalian, Nanjing, Chongqing, Chengdu, Shenyang, Xian, Hangzhou and Suzhou where (Figure 1) the total length of metro under construction are 1471km, 1699km, 2058km, 2408km, 2816.1km, 3195.4km, 3727.5km, 5636.5km and 5816.97km respectively according between 2010 to 2018. Due to its characteristics of high capacity, high efficiency, low pollution and low energy consumption, the subway rail transit system has gradually become the primary means of transportation for people to travel and it plays an increasingly important role in the urban transportation system. Since the closed environment, dense population, difficult evacuation and rescue of Metro-train stations, once an accident happens, it may cause significant losses. Therefore, it is necessary to evaluate the emergency evacuation capacity of Metro-train station [2-7].

With the development of computer technology, researchers use computer technology software to simulate engineering problems. In this paper, AnyLogic simulation software is used to simulate and analyse the emergency evacuation process of Chongqing Daping metro-station. The test result shows emergency evacuation time of this station is 3min 6s. It meets the requirement of China's subway track design standards that the emergency evacuation time to a safe area must be less than 6 minutes.
Figure 1: Length of operating subway lines in China's cities from 2010 to 2018 (in kilometer)

2. Evacuation model and building model

2.1. Evacuation model
Taking Daping Station as an example, two train stations were constructed. There are two lines on the platform floor, and two subway tracks can stop at the station at a time. The station has one entrance and two exits. Passengers walk from the station hall to the platform via the escalator. When fire alarm occur, all of the passengers go the safe area using automatic staircase.

Figure 2: Evacuation model of a Chongqing Daping metro station

2.2. Building model
Based on Daping metro-rail station, a physical model of personnel evacuation which involves the automatic ticket gate, manual ticket gate, baggage-checking machine, ticket gate, automatic staircase and the evacuation passageway is constructed and shown in Figure 3. According to Figure 3, we can
see that the station hall has two escalators, the platform layer has automatic ticket gates, manual ticket gates, ticket machine, ticket gates and two exits (D1, A1). Ticket gate (7) has eight brakes. The specific parameters are shown in Table 1.

Table 1. The specific parameters of a Chongqing Daping metro station

| Area Sector               | Length(m) | Width(m) | Running velocity(m/s) |
|---------------------------|-----------|----------|-----------------------|
| Automatic staircase room  | 15        | 3        |                       |
| Automatic staircase       | -         | 1        | 0.65                  |
| Each brake of ticket gate| 2         | 0.50     |                       |
| Exit                      | -         | 5        |                       |
| Passageway                | -         | 3        |                       |

The structure of a Chongqing Daping metro-rail station has designed using all the parameters. It is worth noting that vertical elevators cannot be used as an evacuation tool according to the standard ‘metro design code’ [8].

![Figure 3. Planned structure of a Chongqing Daping metro station](image)

2.3. Safety index in fire

Architecture codes and fire protection codes in various nations furnish recommendations for constructing designers [9]. Presently, the metro designers and architects in China are attempting to use a performance-based approach to graph and consider the escape system for extra and greater complex metro station. The performance criterion of occupant evacuation in fire engineering is evacuated to a safe spot before the fire environment threatens human safety. And the mathematic expression is:

\[ T_{ASET} > T_{RSET} \]  

Where \( T_{ASET} \) is available Safety Egress Time (ASET), which is the time that fire may hurt person. \( T_{RSET} \) is Required Safety Egress Time (RSET). From Eq. 1, fire evacuation follows these rules, and then safety fire evacuation is occurred in metro-rail station. Available Safety Egress Time (ASET) is 6 minutes and Required Safety Egress Time (RSET) is below 6 minutes. When emergency evacuation time is followed this equation, all of the passengers can go to the safety place.

3. Simulation results and analysis

3.1. Simulation results

(a)-25s. As can be seen from Figure 4(a), when the evacuation time goes to 25s, all passengers run to the escalator entrance in the station platform. At the same time, all passengers in station hall run to ticket gates, causing congestion.
Figure 4(a) the passengers’ distribution after the evacuation time 25s

(b)-50s. After 50s, some passengers have been evacuated to a safe area in the station hall, and some passengers in the platform have commenced to reach the station hall and are going to run to ticket gates and other free exists.

(c)-78s. Most of the passengers in the station hall have been evacuated when the evacuation time goes to 78s. All of the places are in the crowded circumstance and some passengers in the platform have started to arrive at the turnstiles to the station hall.

(d)-156s. Evacuation task finishes in the station hall and only 10 passengers are passing the exit door. After 156s, this situation occurs in the station hall.

(e)-186s. The total emergency evacuation needs 186s. During this simulation, 100 passengers have completed safe operation and the evacuation time was announced as 186 seconds. The safety evacuation time is 3 min 6s.

Figure 4(b) the passengers’ distribution after the evacuation time 50s

Figure 4(c) the passengers’ distribution after the evacuation time 78s
3.2. Analysis of simulation results

Fig. 5 shows the relation between passengers’ number in the platform hall and the time. When the evacuation begins, the evacuation process is relatively fast, with an average of 4 people evacuated every minute. When goes to 17s, 28s and 38s, the escalator evacuation is affected. After 40s, the number of passengers in the platform hall is 25 people. Gradually, passengers are decreasing from the platform. At last, after 70s, the passengers remain zero that means evacuation task has finished in the platform station. Before finishing the whole evacuation process (186s), it doesn’t change.
Fig. 6 shows that the relationship between passengers’ number and the time respectively in the station hall. Passengers’ curve is reducing at the starting of evacuation. Passengers’ line chart begins to increase in the station hall when more passengers have arrived from the platform layer in the time of 25s. After 60s, passengers curve goes to decline. This curve always stands decreasing because of the safety Exit D1 and Exit A1. At last, all the passengers have reached the safety area in the station hall after 186s.

3.3 Results and discussion
From simulation result, The Chongqing Daping metro-train station safety evacuation time is 3 min 6s. It meets the requirement of China's subway track design standards that the emergency evacuation time to a safe area must be less than 6 minutes.

Evacuation simulation shows that there is congestion at the automatic ascending stairs, stairs and ticket gates, which will affect the evacuation time, but in general, the evacuation function of Chongqing Daping station conforms to the subway design specifications.

4. Conclusion
This paper uses AnyLogic software to simulate the emergency evacuation process of Chongqing Daping metro-rail station in the event of an emergency. The test result shows the evacuation time is 3min 6s, which means the design of this station meets the requirement of China's subway track design standards.

In addition, the test results also showed some shortcomings in the design of the subway station such as, the small number of escalators leads to the crowding at the entrance of escalators, the narrow width of the staircase leads to insufficient throughput and so on. These drawbacks make the evacuation time increase. Therefore, Daping subway station needs to correct these shortcomings.

Acknowledgments
The work described in this paper was supported by the National College Students' innovation and entrepreneurship training program (201810617006)

References
[1] Union International des Transports Publics (2018) (International Association of Public Transport).https://en.wikipedia.org/wiki/City_hall
[2] LIANG H J, XU W B. (2012) Performance Analysis on Evacuation in Subway Fire. Journal of Shenyang Jinzhou University Natural Science, 28: 702-709.
[3] YANG L, Detachment D F. (2013) Brief analysis of subway fire safety evacuation. Fire Science and Technology, 671-674: 1081-1086.
[4] XIE H S. (2013) Analysis and calculation of evacuation time for metro fire. Railway Computer Application, 22(9): 62-65. (In Chinese)
[5] YU M G. (2012) Fire risk assessment. Beijing: China Machine Press, 184-187. (In Chinese)
[6] WANG Z L, HUA M, PAN X H. (2015) Comparative study of evacuation planning in subway tunnel fire. Fire Science and Technology, 02. (In Chinese)
[7] ZHANG Z F. (2008) Calculation of safety evacuation time in the subway fire accident. Modern urban transit, 3: 69-70. (In Chinese)
[8] Li Z, Tang M, Liang D. (2016) Numerical simulation of evacuation in a subway station. Procedia Engineering, 135: 616-621.
[9] Shi C, Zhong M, Nong X. (2012) Modeling and safety strategy of passenger evacuation in a metro station in China. Safety Science, 50(5): 1319–1332.