A System Approach on Safe Emergency Evacuation in Subways: A Systematic Literature Review

Fatemeh Nouri1, Davoud Khorasani-Zavareh1,2, Amir Kavousi1,3, Reza Mohammadi4

1Department of Health in Emergencies and Disasters, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 2Workplace Health Promotion Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 3Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 4Department of Neurobiology, Care Sciences and Society (NVS), H1, Division of Family Medicine and Primary Care, Huddinge, Sweden

Abstract

Background: Due to the extensive use of subway transportation in high- and middle-income countries, the safety of passengers has become one of the important challenges in emergency management of subway station. Therefore, the present systematic review aimed to identify environmental and organizational management factors that affect the safe emergency evacuation in subway stations. Materials and Methods: In this systematic literature review, PubMed, Scopus, Web of Science, ProQuest, Google Scholar, Iran Medex, Magiran, and Scientific Information Database from 1990 to 2019 were searched to identify effective emergency management factors in safe emergency evacuation of the subways. A thematic content analysis was employed for data analysis. Results: Of 763 publications retrieved from the searches, 149 studies were included for data analysis. According to the findings, effective environmental and organizational management factors in safe emergency evacuation were discussed in eight subcategories, including infrastructure properties, evacuation-assisting resources, prevention of injuries and mitigation, preparedness for emergency evacuation, emergency response and reconstruction, and maintenance of evacuation facilities. Conclusion: The design of an optimal route for emergency evacuation is the main theme of most studies focusing on environmental factors. While a system approach for designer is needed for effective subway emergency evacuation, human-related factors focusing on injury prevention are also crucial.

Keywords: Emergency evacuation, environmental factors, organizational factors, subway

INTRODUCTION

Although subway transition services in high- and middle-income countries accelerate the transportation of passengers and thus reduce the time spent in urban traffic, they have also turned subway stations into crowded and busy public places.[1,2] Currently, crowded subway stations, especially in peak hours, are quite prevalent.[4] The high density of passengers and the psychological burden of a massive crowd in the limited space of stations and on platforms can easily lead to congestion, formation of queues at bottlenecks and narrow passages, and even a threat to the health of passengers.[6,7] Therefore, emergency evacuation has found an important place in pedestrian safety research, and timely and effective evacuation of stations will be an important measure for preventing injuries.[7,8]

Nowadays, ensuring the safe evacuation of pedestrians from public places, such as subway stations, is a major factor contributing to the quality of services in the development of a healthy and safe rail transportation system.[9-10] The design and construction of emergency exit and egress paths as the shortest path for exit are safety-related issues in the design

Address for correspondence: Dr. Davoud Khorasani-Zavareh, Department of Health in Emergencies and Disasters, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

E-mail: davoud.khorasani@gmail.com

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and implementation of public places.[11,12] During emergency evacuation, certain unpredictable situations, for example, fire, smoke, or the destruction and partial or complete collapse due to natural disasters or anthropogenic hazards, may make it impossible to use predetermined emergency evacuation.[13] Moreover, the unpredictability of human behavior in emergency conditions as well as uncertainty with regard to all environmental and intrinsic variables that affect human behavior leads to the high complexity of emergency evacuation from subway stations and has become a major challenge for planning emergency evacuation.[8,14-18]

As in many domains of organizational performance management, in evaluating the performance of emergency evacuation, the concepts of efficiency and effectiveness are common in determining the level of success or failure of operations.[13] Efficiency is a basic need in emergency evacuation operations.[19] The efficiency of emergency evacuation refers to the ratio of the total number of people evacuated to the total number of people expected to be evacuated through available resources, for example, exit and egress paths, in the time available for evacuation.[19,20] In emergency evacuation aiming at the safe evacuation of people, evacuation with minimum injuries as well as the effectiveness of evacuation operation is of special significance.

In emergency situations such as fire, emergency evacuation is a serious challenge for crowd safety.[21] Thus, the reexamination of capacities and emergency exit paths based on the increased passenger load for each station as well as the identification and clarification of factors promoting the safety of emergency evacuation in subway systems can be applied in planning for promoting crowd safety during emergency evacuation. Accordingly, the present study was designed to identify environmental and organizational management factors affecting the safe emergency evacuation from subway stations by a systematic literature review.

**Materials and Methods**

**Eligibility criteria**

This systematic review included all studies that were conducted from 1990 to 2017, in which the emergency crowd evacuation has been an important dependent or independent variable, or those which have studied emergency evacuation of subway stations using an experimental or simulation approach.

**Literature search and data extraction**

The search strategy consisted of two steps including electronic search and manual search. The search syntax was conducted using emergency evacuation, safety, and subway as main keywords. Furthermore, appropriate synonyms for keywords were identified through Medical Subject Headings terms, popular and common words and phrases stated in related literature, and expert opinion.

The search of electronic databases was performed through PubMed, Scopus, Web of Science, Google Scholar, Iran Medex, Magiran, and Scientific Information Database to identify related articles and literatures. Furthermore, we searched ProQuest for dissertations and other sources such as national and international congresses such as International Conference of Chinese Transportation Professionals and CICTP. Tables of contents of key journals in this field and gray literatures were searched through handsearching. The search strategy was developed and completed in PubMed, and then the same strategy was applied to other databases. Finally, reference lists of relevant articles and systematic reviews were searched as well. The search syntax of databases is given in Appendix 1a and b.

Then, the search was conducted and the publications of interest were selected based on the titles and abstracts. After screening, the full texts of all the selected publications were examined. The relevant data were extracted from identified publications based on the PRISMA flowchart [Figure 1].

All the searched studies included quantitative and qualitative methods, which have aimed for the safety of crowd during emergency evacuation with minimum injuries. Accordingly, studies on emergency evacuation in places other than subway stations and underground stations were not included. Therefore, all studies on emergency evacuation of bus stations, urban tunnels, and public buildings were excluded. Moreover, this study focused on the safe emergency evacuation after the exploitation of subway lines. Therefore, all studies focusing on emergency evacuation in the construction phase of subway stations were excluded. To avoid language bias, non-English publications were also included, and Google Translate was used to extract the data in these articles.

**Review, data extraction, and quality assessment**

All studies’ records transmitted in (EndNote X7™, Thomson Reuters) software and initially duplicated records were extracted. In the next step, primary article screening was conducted by two authors independently. They reviewed the title and abstract of the articles independently and categorized the selected articles into relevant, irrelevant, and unsure groups. Irrelevant articles were eliminated from the study, and for unsure categories, the third author decided the articles. Then, after reviewing the full text of relevant articles by each reviewer, they made a list of included articles.

From each included study, the following information of studies including the name of the author, the type of the study, study design, and outcome has been extracted [Table 1].

Moreover, factors affecting the safe evacuation of the subway under emergency conditions were extracted from the included papers and entered into data sheets [Appendix 2] by two reviewers. To do data synthesis of findings, a six-phase framework of thematic analysis was used based on Braun and Clarke (2006) recommendations.[22] Therefore, the following steps were employed by a three-researcher team. These steps followed becoming familiar with the data, generation of initial codes, searching for themes, reviewing themes, defining themes, and writing up the manuscript.[22] Two reviewers performed data extraction independently and
consensus reached. In some instances, when reviewers did not get consensus about codes and categories, coding procedures have been revised by the third researcher. Moreover, reviewing of emerging data and data analysis among the research group was discussed.

Critical appraisal of articles was performed by the authors employing a developed checklist [Appendix 3] to assess the quality of each article based on four categories, including screening question, study design/type of the study, findings, and strength of recommendation. All of the studies included were reviewed on the basis of this checklist’s questions.

**Results and Discussion**

**Search results**

Based on the PRISMA flowchart, from 763 studies searched using the syntax search on databases, the full texts of 277 studies were examined based on the correspondence of title and abstracts with inclusion and exclusion criteria. Finally, 149 articles were included in this study, and emergency management factors affecting safe emergency evacuation of subway stations were extracted from their results sections and were analyzed based on thematic analysis.

Of all studies searched after the removal of duplications, 326 studies were excluded as they did not meet inclusion criteria. A total of 277 studies entered the risk of bias assessment phase, and the full texts of these studies were examined based on the critical appraisal checklist; seven studies were excluded as they did not include factors related to the present systematic review and seven were excluded as they focused on the vulnerability of subway stations and resilience of the public transportation system. Furthermore, 95 studies examined the subway evacuation in normal condition and 9 studies investigated evacuation during the construction operations of subway stations. As emergency evacuation occurs after the exploitation of stations, these studies were excluded. Moreover, of 277 studies whose full texts were examined, only four studies had a qualitative method; three of them meet the inclusion criteria. Therefore, all majority of studies included here were quantitative.

Among the primary studies, 90 studies were journal articles, 42 were conference paper, 2 were book section, and 6 were thesis. The majority of study designs of publications were 91 simulation studies, 6 mathematical modeling, 10 cross-sectional and 26 case studies and 6 reviews and 1 trial were also considered. The studies were mostly conducted in subway stations of China [Table 1].
Table 1: Specifications of studies included in the systematic review of environmental and organizational management-related factors in safe emergency evacuation from subways

| Authors                        | Years | Country     | Type            | Design                       | Finding focus of articles                                                                 |
|--------------------------------|-------|-------------|-----------------|-----------------------------|------------------------------------------------------------------------------------------|
| Zhang, Limao[22]               | 2019  | China       | Journal article | Simulation/case study       | Prevention of injuries and mitigation                                                      |
| Wang W[23]                     | 2018  | China       | Journal article | Simulation                  | The effect of injuries and mitigation                                                      |
| Lee HS[24]                     | 2018  | South Korea | Journal article | Simulation                  | The effect of environmental factor in emergency response                                   |
| Yang J[25]                     | 2017  | China       | Journal article | Mathematical modeling/case study | Emergency response                                                                        |
| Wang Z[26]                     | 2017  | United States | Conference paper | Simulation                  | Emergency response                                                                        |
| Wang, Qiquan[27]               | 2017  | China       | Journal article | Case study                  | Prevention of injuries and mitigation                                                      |
| Sui J[28]                      | 2017  | China       | Journal article | Simulation                  | Preparedness                                                                             |
| Ma L[29]                       | 2017  | China       | Journal article | Simulation                  | Preparedness                                                                             |
| Li Q[30]                       | 2017  | China       | Journal article | Simulation                  | Emergency response                                                                        |
| Chen SK[31]                    | 2017  | China       | Journal article | Simulation                  | Emergency response                                                                        |
| Butler K[32]                   | 2017  | United States | Journal article | Case study/qualitative      | Emergency response                                                                        |
| Baffoe BOK[33]                 | 2017  | China       | Journal article | Case study/FGD/qualitative  | Preparedness                                                                             |
| Zhang et al.[34]               | 2017  | China       | Journal article | Mathematical modeling       | Safe egress time of emergency evacuation                                                  |
| Wu et al.[35]                  | 2017  | China       | Journal article | Simulation                  | Estimate evacuation capacity under emergency conditions                                   |
| Jevtic, Radoje B[36]           | 2017  | Serbia      | Journal article | Simulation                  | The possible evacuation situation and calculate minimum time needed for evacuation        |
| Chen YX[37]                    | 2017  | China       | Journal article | Simulation                  | Resources assisting evacuation to arrive at safety zones                                   |
| Chen T[38]                     | 2017  | China       | Conference paper | Cross-sectional             | Prevention of injuries and mitigation by improve the safety equipment effectiveness       |
| Chen SK[39]                    | 2017  | China       | Journal article | Simulation                  | Effectiveness of infrastructure properties in emergency evacuation                        |
| Ye QW[40]                      | 2016  | China       | Conference paper | Case study                  | Preparedness                                                                             |
| Yang YD[41]                    | 2016  | China       | Journal article | Case study                  | Preparedness                                                                             |
| Qian Q[42]                     | 2016  | China       | Journal article | Case study                  | Prevention of injuries and mitigation                                                     |
| Luo H[43]                      | 2016  | China       | Conference paper | Ontology/qualitative        | Preparedness                                                                             |
| Lu K[44]                       | 2016  | China       | Journal article | Case study                  | Prevention of injuries and mitigation                                                     |
| Li, Qiming[45]                 | 2016  | China       | Journal article | Simulation/case study       | Preparedness                                                                             |
| Karagiannisidis L[46]         | 2016  | Greece      | Conference paper | Case study                  | Emergency response                                                                        |
| Ju Kim, Hyan[47]               | 2016  | South Korea | Journal article | Factor analysis             | Preparedness                                                                             |
| Haghani M[48]                  | 2016  | Australia   | Journal article | Random-utility analysis     | Emergency response                                                                        |
| Fridolf K[49]                  | 2016  | Sweden      | Journal article | Cross-sectional             | Emergency response                                                                        |
| Brüne M[50]                    | 2016  | Germany     | Journal article | Simulation                  | Emergency response                                                                        |
| Maslak V[51]                   | 2016  | Russian Federation | Conference paper | Simulation                  | The effect of environmental structure in safety of evacuation                              |
| Ma J[52]                       | 2016  | China       | Journal article | Simulation                  | The efficient passenger emergency evacuation process                                      |
| Lin-na, CHENG[53]              | 2016  | China       | Journal article | Simulation                  | The effect of environmental factors in a subway station fire evacuation process            |
| Hong L[54]                     | 2016  | China       | Journal article | Simulation                  | Improving emergency response                                                               |
| Chang HP[55]                   | 2016  | Taiwan      | Journal article | Simulation                  | The effect of incidents features on emergency evacuation                                  |
| Cai Yu[56]                     | 2016  | China       | Journal article | Simulation                  | The effect of incidents features on emergency response                                     |
| BAYSAL TÜRKÖLMEZ, Gökçe[57]    | 2016  | Turkey      | Journal article | Simulation                  | The safe egress time                                                                       |
| Sharma S[58]                   | 2015  | United States | Conference paper | Simulation                  | Preparedness                                                                             |
| Chen YY[59]                    | 2015  | China       | Journal article | Simulation                  | The environmental and managerial requirement for safe evacuation                           |
| Clapa, Iwona[60]               | 2015  | Poland      | Journal article | Case study                  | Emergency response                                                                        |

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| Authors               | Years | Country       | Type               | Design         | Finding focus of articles                                                                 |
|----------------------|-------|---------------|--------------------|----------------|------------------------------------------------------------------------------------------|
| Yin K[58]            | 2015  | China         | Conference paper   | Trial          | The environmental requirement for prevention of injuries and mitigation                    |
| Yin K[59]            | 2015  | China         | Conference paper   | Simulation     | The environmental requirement for prevention of injuries and mitigation                    |
| Yang X[60]           | 2015  | China         | Journal article    | Simulation     | The environmental requirement for prevention of injuries and mitigation                    |
| Wang ZL[61]          | 2015  | Amsterdam     | Book section       | Simulation     | Emergency response                                                                       |
| WANG, Qi-quan[62]    | 2015  | China         | Journal article    | Mathematical modeling | Emergency response                                                                       |
| Tong R[63]           | 2015  | China         | Journal article    | Simulation     | The environmental requirement for prevention of injuries and mitigation                    |
| Xu, Yan Ying[64]     | 2014  | China         | Conference paper   | Case study     | Emergency response                                                                       |
| Wang Z[65]           | 2014  | China         | Conference paper   | Simulation     | Preparedness                                                                             |
| Sun XB[66]           | 2014  | China         | Journal article    | Cross-sectional | Preparedness                                                                             |
| Li, Zhu Huan[67]     | 2014  | China         | Conference paper   | Simulation     | Prevention of injuries and mitigation                                                     |
| Li Q[68]             | 2014  | China         | Conference paper   | Case study     | Emergency response                                                                       |
| Han X[69]            | 2014  | China         | Journal article    | Simulation     | Emergency response                                                                       |
| Tong R[70]           | 2014  | China         | Journal article    | Cross-sectional | Emergency response                                                                       |
| Zeng S[71]           | 2014  | China         | Conference paper   | Simulation     | The effect of incidents feature on safe evacuation                                        |
| Xie, Hua[72]         | 2014  | China         | Conference paper   | Review         | The safe emergency evacuation strategies                                                 |
| Xie, Hua[73]         | 2014  | China         | Conference paper   | Review         | The evacuation strategy of safe emergency evacuation                                     |
| Wang WL[74]          | 2014  | China         | Conference paper   | Simulation     | The environmental requirement for emergency response                                     |
| Qu Yunchao[75]       | 2014  | China         | Journal article    | Simulation     | The effect of incidents feature on safe evacuation                                        |
| Lo SM[76]            | 2014  | China         | Journal article    | Simulation     | The effect of design on prevention of injuries and mitigation                             |
| Liu Fang Lin[77]     | 2014  | China         | Journal article    | Simulation     | The effect of design on prevention of injuries and mitigation                             |
| Liao Weiachen[78]    | 2014  | China         | Journal article    | Simulation     | The environmental requirement for emergency response                                     |
| Zhang Su Li[79]      | 2013  | China         | Journal article    | Fuzzy network analysis | Emergency response                                                                       |
| Yi SL[80]            | 2013  | China         | Journal article    | Simulation     | Emergency response                                                                       |
| Yang H[81]           | 2013  | China         | Conference paper   | Case study     | Emergency response                                                                       |
| Wang X[82]           | 2013  | China         | Conference paper   | Simulation     | Emergency response                                                                       |
| Song Y[83]           | 2013  | China         | Journal article    | Simulation     | Emergency response                                                                       |
| Li YF[84]            | 2013  | China         | Journal article    | Cross-sectional | Emergency response                                                                       |
| He, Jian-Fei[85]     | 2013  | China         | Journal article    | Case study     | Prevention of injuries and mitigation                                                    |
| Yue H[86]            | 2013  | China         | Journal article    | Simulation     | The environment requirement for safe emergency evacuation                                 |
| Yang, Peizhong[87]   | 2013  | China         | Journal article    | Simulation     | The effect of environmental factors on emergency evacuation                              |
| Tachibana, H[88]     | 2013  | Japan         | Conference paper   | Review         | The environmental requirement to prevention of injuries and mitigation                   |
| Ronchi, Enrico[89]   | 2013  | Sweden        | Journal article    | Simulation     | Prevention of injuries and mitigation                                                    |
| Pflicht, Andreas[90] | 2013  | Germany       | Journal article    | Simulation     | The effect of incidents feature on safe evacuation                                        |
| Jiahui, W[91]        | 2013  | China         | Conference paper   | Simulation     | The effect of incidents feature on safe evacuation                                        |
| HE, Li-gong[92]      | 2013  | China         | Journal article    | Case study     | The effect of environmental design on emergency response                                  |
| Fridolf, K[93]       | 2013  | Sweden        | Journal article    | Mathematical modeling | The environmental requirement to prevention of injuries and mitigation               |
| Choi, J[94]          | 2013  | Japan         | Conference paper   | Simulation     | The environmental requirement to prevention of injuries and mitigation                   |
| Authors                  | Years | Country | Type          | Design       | Finding focus of articles                                                                 |
|-------------------------|-------|---------|---------------|--------------|------------------------------------------------------------------------------------------|
| Wang, Y(93)             | 2012  | China   | Conference paper | Case study  | Emergency response                                                                        |
| Kadokura, H(94)         | 2012  | Japan   | Journal article | Simulation   | Emergency response                                                                        |
| Okada, N(97)            | 2012  | Japan   | Journal article | Case study   | Emergency response                                                                        |
| Nguyen, Manh Hung(98)   | 2012  | Vietnam | Conference paper | Simulation   | Prevention of injuries and mitigation                                                     |
| Yiheng, Wang(99)        | 2012  | China   | Journal article | Mathematical modeling | The effect of evacuation capacity on emergency evacuation |
| Qu, L(100)              | 2012  | China   | Journal article | Simulation   | The environmental requirement to prevention of injuries and mitigation                   |
| Liu, Jun Feng(101)      | 2012  | China   | Conference paper | Simulation   | Emergency response                                                                        |
| Liang, H(102)           | 2012  | China   | Journal article | Simulation   | The effect of incident feature on emergency evacuation                                    |
| Li, Y, F(103)           | 2012  | China   | Book section   | Simulation   | The effect of environment on safe emergency evacuation                                     |
| Han, X(104)             | 2012  | China   | Conference paper | Simulation   | The effect of incident feature on emergency evacuation                                     |
| Guo, C(105)             | 2012  | China   | Conference paper | Case study   | Prevention of injuries and mitigation                                                    |
| Gao, R(106)             | 2012  | China   | Journal article | Simulation   | The environmental requirement to prevention of injuries and mitigation                   |
| Cheng, Huan(107)        | 2012  | China   | Journal article | Simulation   | Prevention of injuries and mitigation                                                    |
| Shouei, Mozhdeh(108)    | 2012  | Iran    | Conference paper | Simulation   | The environmental requirement to safe emergency evacuation                               |
| Tian, Juan-Rong(109)    | 2011  | China   | Journal article | Simulation   | Prevention of injuries and mitigation                                                    |
| Li, He(110)             | 2011  | China   | Book section   | Cross-sectional | Preparedness                      |
| Hong, Ling(111)         | 2011  | China   | Conference paper | Cross-sectional | Prevention of injuries and mitigation       |
| Li et al(112)           | 2011  | China   | Conference paper | Simulation   | The effect of environment on crowd congestion during emergency evacuation             |
| Tsukahara, M(113)       | 2011  | Japan   | Journal article | Simulation   | The effect of environment design on emergency evacuation                              |
| Yang, J, T(114)         | 2011  | China   | Conference paper | Simulation   | The environmental requirement to prevention of injuries and mitigation               |
| Wang, Chao(115)         | 2011  | China   | Thesis         | Simulation   | The environmental requirement to prevention of injuries and mitigation              |
| Marsella, S(116)        | 2010  | Italy   | Conference paper | Cross-sectional | Prevention of injuries and mitigation                      |
| Liu, Y(117)             | 2010  | China   | Conference paper | Simulation   | Emergency response                                                                        |
| Zhang, Hong(118)        | 2010  | China   | Journal article | Simulation   | Emergency response                                                                        |
| WU, Jiaorong(119)       | 2010  | China   | Journal article | Case study | Preparedness for emergency response                                                     |
| Roh, J, S(120)          | 2010  | South Korea | Journal article | Simulation   | The environmental requirement to prevention of injuries and mitigation               |
| ZHANG, Peihong(121)     | 2009  | China   | Journal article | Case study | Preparedness                                                                             |
| Weiwei, Kong(122)       | 2009  | China   | Journal article | Case study | Emergency response                                                                        |
| Ishigaki, T(123)        | 2009  | Japan   | Conference paper | Simulation   | Prevention of injuries and mitigation                                                   |
| Huan, Pei(124)          | 2009  | China   | Journal article | Literature review | Preparedness                                             |
| Ceng, Sheng(125)        | 2009  | China   | Thesis         | Simulation   | The safe egress time                                                                     |
| Dezhi, Zhang(126)       | 2009  | China   | Journal article | Case study | The effect of environment factor on Prevention of injuries and mitigation     |
| Xu, X(127)              | 2009  | China   | Conference paper | Cross-sectional | The environmental requirement to prevention of injuries and mitigation |
| Wang, B, H(128)         | 2009  | China   | Book            | Simulation   | The environmental requirement to prevention of injuries and mitigation              |
| Vittori, F(129)         | 2009  | Venezuela | Conference paper | Simulation   | The effect of incident feature on emergency evacuation                                  |
| Tan et al(130)           | 2009  | China   | Conference paper | Simulation   | The environmental requirements for emergency response                                    |
| Roh, J, S(131)          | 2009  | South Korea | Journal article | Simulation   | The environmental requirement to prevention of injuries and mitigation       |
| Ma, Jun-Chi(132)        | 2009  | China   | Journal article | Simulation   | The safe evacuation time                                                           |

Contd...
Table 1: Contd...

| Authors            | Years | Country    | Type               | Design       | Finding focus of articles                                                                 |
|--------------------|-------|------------|--------------------|--------------|------------------------------------------------------------------------------------------|
| Jiang, C. S[130]   | 2009  | China      | Journal article    | Simulation   | The environmental requirement to prevention of injuries and mitigation                     |
| Jeon and Hong[137] | 2009  | South Korea| Journal article    | Case study   | Prevention of injuries and mitigation                                                       |
| Shi, Wei Bo[131]   | 2008  | China      | Thesis             | Simulation   | Prevention of injuries and mitigation                                                       |
| Shi, C. L[132]     | 2008  | China      | Book               | -            | Emergency response                                                                        |
| Liu, S[133]        | 2008  | China      | Journal article    | Simulation   | Emergency response                                                                        |
| Liu, Q. Q[134]     | 2008  | China      | Book               | -            | Emergency response                                                                        |
| Bao, L[135]        | 2008  | China      | Conference paper   | Simulation   | The environmental requirement to prevention of injuries and mitigation                     |
| Zhou, R[136]       | 2008  | China      | Journal article    | Simulation   | The effect of incident feature on emergency evacuation                                      |
| Zhuo, R[137]       | 2008  | China      | Journal article    | Simulation   | The possibility of safe emergency evacuation                                                |
| Zhong, M. H[138]   | 2008  | China      | Journal article    | Simulation   | The environmental requirement for emergency response                                        |
| Zhao, Liang Jin[139] | 2008  | China      | Thesis             | Simulation   | Prevention of injuries and mitigation                                                       |
| Song, B[140]       | 2008  | China      | Journal article    | Case study   | The effect of environmental design on Prevention of injuries and mitigation                 |
| Shi, C[141]        | 2008  | China      | Conference paper   | Simulation   | The effect of environment design on Prevention of injuries and mitigation                   |
| Nie[11]            | 2008  | China      | Thesis             | Case study   | The effect of safety egress design on emergency evacuation                                  |
| LIAO, Yan-fen[142] | 2008  | China      | Journal article    | Simulation   | The environmental requirement for emergency response                                        |
| Chow, W. K[143]    | 2008  | China      | Journal article    | Simulation   | The effect of waiting time on safety management                                             |
| Tokunaga, Takeshi[144] | 2007  | Japan      | Journal article    | Cross-sectional | Prevention of injuries and mitigation                                                        |
| Chang, S[145]      | 2007  | Taiwan     | Journal article    | Simulation   | The effect of incident feature on emergency evacuation                                      |
| Chen, J. H[146]    | 2007  | China      | Book               | Simulation   | The effect of incident feature on emergency evacuation                                      |
| Li, Y. F[147]      | 2007  | China      | Journal article    | Simulation   | The environmental requirement to safe emergency response                                    |
| Mao, F[148]        | 2007  | China      | Journal article    | Simulation   | The effect of incident feature on emergency evacuation                                      |
| Zhang, P[149]      | 2007  | China      | Journal article    | Simulation   | The environmental requirement to prevention of injuries and mitigation                     |
| Yan, TONG[150]     | 2006  | China      | Journal article    | Mathematical modeling | Prevention of injuries and mitigation                                                        |
| Xie, J[151]        | 2006  | China      | Book               | -            | Emergency response                                                                        |
| Haack, A[152]      | 2006  | Germany    | Journal article    | Case study   | Prevention of injuries and mitigation                                                       |
| Landow[5]          | 2006  | United States| Conference paper   | Review       | The prevention requirement for emergency evacuation                                        |
| Li, J. F[153]      | 2006  | United States| Book               | Simulation   | The safe egress time                                                                       |
| Li, Yao-zhuang[154]| 2006  | China      | Journal article    | Simulation   | Prevention of injuries and mitigation                                                       |
| Miclaus, P. C[155] | 2006  | United States| Conference paper   | Review       | The effect of incident feature on emergency evacuation                                      |
| Xie, F[156]        | 2005  | China      | Book               | -            | Prevention of injuries and mitigation                                                       |
| Castle, C. J. E[157]| 2005  | United Kingdom| Book section      | -            | Preparedness                                                                              |
| Moriyama, S[158]   | 2005  | Japan      | Conference paper   | Simulation   | The effect of incident features on safe evacuation                                          |
| Rie, D. H[159]     | 2005  | China      | Book               | -            | Disaster prevention at subway platform                                                      |
| Chien, S[160]      | 2004  | Taiwan     | Journal article    | Simulation   | Preparedness                                                                              |
| Yang and Lee[161]  | 1999  | Taiwan     | Journal article    | Simulation   | The effect of egress design in emergency evacuation                                        |

FGD: Focus group discussion

**Thematic analysis**

Based on the findings of the present study, factors affecting the safe emergency evacuation of subway stations are classified into two main categories and eight subcategories, including...
environmental factors (infrastructure properties, resources assisting evacuation, time, and features of incidents) and organizational management-related factors (prevention of injuries and mitigation, preparedness for emergency evacuation, emergency response, and reconstruction and maintenance of evacuation facilities) [Table 2].

**Environmental factors**

Based on the findings, subway station infrastructure properties, evacuation-assisting resources, time, and features of incidents were the most important environmental factors affecting the safe emergency evacuation from subway stations.

**Infrastructure properties**

In general, based on the examination of the studies, 131 studies investigated the effects of subway station infrastructure properties on the effective and safe emergency evacuation. Based on the results, the identification of safe evacuation paths and identification and evaluation of safety egress paths are the most important features related to the infrastructure of emergency evacuation from subway systems, mentioned by multiple studies. In evaluating evacuation paths, the number of exits, width of exits, passing capacity, walking distance to the exit or the length of the evacuation path, width of corridors, and identification of bottlenecks and connecting corridors’ capacity of the evacuation path were examined. The design of an optimal path for emergency evacuation was also identified as a factor increasing the efficiency and reliability of emergency evacuation.

Other station infrastructure features include emergency facilities such as stairs, ramps, escalators, and elevators. Increasing the number of evacuation paths, width and size of stairs and exits, and number of escalators for improving the emergency evacuation capacity were simulated in numerous studies as variables affecting the duration of evacuation. Diversity and design of evacuation facilities for emergency situations must be proportionate to the need and demand of the population using the subway system, especially regarding those with special needs. The safety of passengers, prohibiting the use of elevators in fire, evacuation through emergency exit stairs, and transfer of crowd to a predetermined safety zone have been recommended. Moreover, the results of simulation case studies of subway station emergency evacuation show that evacuation has a better performance with escalators than with stairs; therefore, in case of failure of elevators, access to escalators as an alternative facility is essential.

Another infrastructure that affecting the duration of effective evacuation in most subway stations is turnstiles and exit gates, which effects on evacuation duration and crowd safety during evacuation, which have been examined in case studies and experimental studies on stations in terms of type, number, and location. Furthermore, the effects of availability of a platform shield door system, platform screen doors, and fire-resistant doors on preventing the spread of smoke and enhancing the safety of passengers in normal and emergency situations have been investigated by numerous studies.

The use of wireless sensor network technology in stations as an effective infrastructure for the safe evacuation of subway stations allows the monitoring of all parts of the station, especially blind spots; improves decision-making duration and implementation of emergency response commands by the timely identification of danger; and promotes the efficiency of evacuation.

The physical properties of the design of subway stations and complicated structure of each station in terms of number of stories, depth, architecture, obstacles considered in the design of the building, location of exits, location and layout of ticket inspectors in the internal space, and the width of the platform

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**Table 2: Environmental and organizational management-related factors in safe evacuation from subway stations based on a systematic review**

| Category                              | Subcategory                          | Examples from the code/data                                    |
|---------------------------------------|--------------------------------------|---------------------------------------------------------------|
| Environmental factors                 | Infrastructure properties             | Identification and evaluation of evacuation routes            |
|                                       | Escape-assisting resources            | Rescue equipment for emergencies                              |
|                                       | Time                                 | Accident time                                                 |
|                                       | Features of incidents                 | Type of accident (terrorist attack, fire, etc.)               |
| Organizational management-related factors | Mitigation of injuries               | Safety risk management                                        |
|                                       | Preparedness for emergency evacuation| suitable emergency evacuation plan                            |
|                                       | Emergency response                    | decision-making for response operations                       |
|                                       | Reconstruction and maintenance of evacuation facilities | Continues reconstruction plans                                |
|                                       |                                      | Features of subway station                                    |
|                                       |                                      | Determine safe zones in subway tunnels and stations            |
|                                       |                                      | Staff who guides evacuation                                   |
|                                       |                                      | Total evacuation process time                                  |
|                                       |                                      | Severity and extent of the accident                           |
|                                       |                                      | Determining congestion level for station evacuation           |
|                                       |                                      | Emergency drillings                                           |
|                                       |                                      | Effective and timely response                                 |
|                                       |                                      | Calibration of firefighting equipment of stations              |
are the other infrastructure features of stations whose effects on evacuation capacity and duration of safe evacuation have been analyzed in simulation case studies of emergency evacuation of certain stations, including those in China. [97,75-78] The results of a case study in Japan also indicated that the acoustics of the space affect the effective notification and safety of evacuation. [79] In the domain of evacuation safety, from among the infrastructure features of stations, the number of stories (due to increasing duration of emergency evacuation) and the architecture of the space (due to the importance of identification of bottlenecks) received special attention. For instance, angular or winding paths affect the formation of bottlenecks and lead to the aggregation of the crowd. [80-82]

With regard to the effects of subway station infrastructure properties, the features of the underpasses of the subway stations affect the safe evacuation of crowd. In addition to the effects of underpass evacuation capacity on the required safe egress time (RSET), based on a survey of the subway system in China, filling the space of underpasses by street vendors highly affected the efficiency of emergency evacuation by limiting the space available for evacuation. [83] Therefore, our findings concluded that the removal of all obstacles limiting exit paths is essential in terms of the safety of evacuation. Furthermore, another factor affecting safe evacuation in normal and emergency conditions emphasized by different studies is the necessity of respecting station design safety codes, including evacuation path design codes, evacuation safety zone codes, and the American National Fire Protection Association standard codes (NFPA130) in the design of stations. [15,27,52,84-92]

Ventilation systems in the station and tunnel ventilation are subway station design, construction, and exploitation requirements. [73,93] The number, conditions, and effective performance of this infrastructure in relation to the safety of passengers in emergency conditions and ventilation strategies were discussed in numerous studies as factors that affect the effective emergency evacuation. [25,61,73,94-105] On the other hand, installation of emergency lights in the infrastructure of subway stations and its effective performance affect the safety of passengers during evacuation at the time of power outage in stations, trains, and tunnels. [16,84,98]

**Evacuation-Assisting Resources**
In this systematic review, resources assisting evacuation were another environmental factor that affects the safe emergency evacuation and discussed in thirty studies. These resources are divided into two groups, physical and human resources. Physical resources include emergency equipment in the station, covering alarm bell, fire extinguishers, and emergency ladder; emergency equipment in the tunnel, including loudspeakers with alarm signal and notification of voice messages; and relief and rescue resources, covering evacuation mattresses, all serving as safety requirements of subway stations. The importance of the availability and functioning of this equipment is undeniable in emergency situations. [56,86,106-109] In signage systems for subway stations, instructions, emergency exit signs, and ground signs are the physical resources assisting emergency evacuation. The quick and smooth evacuation of passengers depends on instruction services provided by signage systems. These systems are a tool for static direction finding, accelerating evacuation by reducing the time to find directions and increasing the certainty of passengers during escape. [108,110-116] The effects of the position of these signs and their visibility on the facilitation and acceleration of evacuation have been discussed by several studies on subway station emergency evacuation. [111,115,117-119] Furthermore, the positive effect of direction-finding lighting facilities on the safety of evacuated people has been studied. [120,121] It is important to note that the importance of visibility have discussed in prevention of other type of accidents. In addition, emergency notification audio systems in stations, including the adequacy of loudspeakers in terms of quality and quantity, and smart public alarm systems are among physical resources examined with regard to emergency evacuation. [51,79] In terms of human resources, the directive, assistive, and relaxing role of the personnel and the help of evacuation assistants in emergency situations have been identified in several studies as facilitating the dynamism of emergency evacuation operations. [122-125]

**Time**
Another environmental factor affecting emergency conditions discussed in the studies included in the present review is time. Twenty studies discussed the importance of time in subway station emergency evacuation in their results sections. In studies on emergency evacuation, time considerably affects the efficiency of evaluation. [27,33] The effect of the time of incidents (e.g. rush hour and duration of blockage of exits) on the severity of incidents has been discussed in relevant studies, and the results have demonstrated that minimization of wait time for passengers in crowded situations is effective on the implementation of emergency evacuation safety management at the time of incident. [126] Furthermore, emergency situation response time and analysis of evacuation time, i.e., the duration of time taken to fully evacuate the station, have been examined in studies as variables affecting evacuation safety. [25,28,33,100,127-129] For a safe evacuation, the required safe egress time (RSET) must be shorter than the available safe egress time (ASET). [21,130] ASET is the time duration of hazard occurs until the time in which it starts eliminating the safety of the crowd. In the theory of evacuation process, RSET includes the identification of hazard and evacuation response. Total alarm time is the response time and evacuation action time, varying based on smoke control, increased ambient temperature, and the change in smoke concentration, thereby affecting the possibility of effective evacuation. [17,31]

**Features of incidents**
The final category of studies examining the effects of environmental factors on subway station emergency evacuation comprises studies on the conditions of emergency evacuation based on the features of the accident. In 32 studies, the features of the accident have been investigated as factors affecting the efficiency of evacuation. In accidents leading to the emergency evacuation of subway stations, the safety of the crowd has been
examined in relation with the location of accident, which may be the tunnel, platform, or inside the train. Depending on the type of hazard, the location of accident, situation of evacuation in the tunnel or on the platform, and the distance from the source of hazard to the crowd greatly affect the safety of crowd during emergency evacuation.\[27,73,94,101,132-135]\n
In terrorist attacks or the accidental dissemination of hazardous substances in the subway, the effects of the position of the source of gas and dispersion of the toxic agent in the system with or without the movement of the train provide key data for helping rescue and escape procedures.\[136,137]\n
In simulation of fire accidents in subway stations, the degree, intensity, and spread of accident, including the fire growth rate, heat transfer rate, increase in ambient temperature, and smoke layer height and visibility, are features of the accident examined as factors affecting the efficiency of evacuation.\[15,138-144]\n
In some studies, the effects of smoke in emergency evacuation during fire have been modeled, and the effects of smoke spread have been examined on the safety of passengers.\[24,100,145-149]\n
Smoke of fire and its direction in evacuation paths increase the duration of evacuation and disrupt the evacuation process, because it limits the possibility of accessing and using exits, and therefore, passengers select a safe passage free from smoke increased of the shortest passage. Because of the limitations on the use of exits due to congestion in other exits, the evacuation safety of passengers will be affected.\[12,15,68,94,144,150,151]\n
Factors related to the features of the accident, including the type, source, and location of hazard, seriously affect evacuation duration, effectiveness, and efficiency. Researchers conclude that, in most studies, the effects of the features of accidents on human reaction and physiologic tolerance of human health have been neglected. For example, smoke affects psychological and physiological conditions, increasing fear and difficulty breathing for those caught in fire, thereby reducing the speed of movement in evacuation.\[150]\n
Alternatively, the threshold of humans’ tolerance of ambient temperature affects their walking speed during evacuation and may even stop human functioning in case of exacerbation of accidents. Thus, future studies on safety and health in disasters and emergencies must further examine the effects of the features of accidents on human health and functioning in different accidents by identifying variables affecting human health in subway station emergency evacuation.

In general, with regard to studies that examine and simulate subway station emergency evacuation in the form of case studies and experimental studies, it can be concluded that environmental modification is among the most effective factors for improving subway evacuation processes, because the results of most studies in this systematic review confirm that, by changing and modifying the environment, the level of human error can be largely compensated for, and effective measures can be taken to ensure a higher degree of safety. In addition to studies in the domain of rail transport, in the majority of studies examining the promotion of crowd safety in busy public places, including hospitals, estimation of the structural safety status of the location in crowd safety during disasters and emergencies as modifiable or adjustable variable has attracted the attention of researchers in the domain of health.\[152]\n
**Organizational management-related factors**

The results extracted from these studies show that some factors related to urban rail transport system and subway station management affect the safe emergency evacuation. In the present study, these factors were classified under the following four categories: prevention of injuries and mitigation; preparedness for evacuation; emergency response; and equipment and rail transport systems reconstruction, maintenance, and updating.

**Mitigation of injuries**

Mitigation of passengers’ injuries and evacuation risk reduction are factors affecting the performance of a safe emergency evacuation during accidents or emergency situations. In this systematic review, numerous studies have been found on mitigation actions and measures affecting the safe emergency evacuation of subway stations.\[153-155]\n
The safety risk management of underground stations and the use of innovation safety risk management of underground transportation are discussed in literatures as factors affecting the mitigation of injuries during emergency evacuations.\[150,156-159]\n
Design of safety risk management regulations, implementation of safety risk management strategies and plans in subway stations, and the development of a decision support system for emergency evacuations have been proposed as injury mitigation strategies during emergency evacuations.\[157,160]\n
In many studies on simulations of subway station emergency evacuation, controlling the number of passengers entering and exiting trains and stations, management of crowd movement flow in bottlenecks, improvement of passenger movement between lines, and identification of crowd aggregation patterns in stations have been examined as factors affecting the efficiency of evacuation during emergency situations.\[161-163]\n
Evaluating the safety of evacuation paths, optimization of evacuation paths based on subway safe evacuation requirements in order to optimize the performance of emergency evacuation, and estimation of the stations’ evacuation capacity have been examined by several relevant studies.\[19,148,164-166]\n
Despite the existence of several studies on safety risk management in underground stations, there is still a dearth of research in determining the level of emergency for notifying early warning to evacuation or presentation of a decision-making tool for notifying emergency evacuation. This demonstrates the necessity of examining these topics in future studies.

**Preparedness for emergency evacuation**

Preparedness for emergency evacuation is a factor related to the management of rail transportation systems affecting the safe evacuation during emergencies.\[167]\n
In studies on subway station emergency evacuation, the development of a suitable program...
for responding to emergency situations, planning for determining evacuation paths during emergencies, and the development of an emergency evacuation plan for the station have been considered as preparedness activities for safe emergency evacuation.\

Similarly, identification of optimal escape paths in station evacuation maps (e.g., determining evacuation paths as separate from smoke paths or a safe evacuation route) and organizing emergency rescue teams and emergency drilling have been discussed as factors affecting the preparedness of stations for performing emergency evacuation. Although the identification and mitigation of station vulnerabilities are important factors for the preparedness and development of emergency evacuation programs, few studies have focused on the mitigation of evacuees. It implies on more research in this area, of which the current researchers are conducting with a focus on the stakeholders’ perception on factors affecting mitigation of passengers.

In addition to organizational preparedness, personnel and passenger preparedness for an emergency evacuation response is important. In some studies, the effects of educational programs on railway safety and awareness programs for passengers have been examined in preparedness for emergency response.

**Emergency response**

According to this systematic review, emergency response is an important factor related to subway station management. To ensure the life safety and safe functioning of the subway system in emergency situations, the capability of emergency evacuation and quick and effective evacuation are highly important. Identification of emergency response processes appropriate for the incident and implementation of emergency evacuation procedures management of crowd movement flow during emergency evacuation in exit paths, and management of facilities (passages, escalators, and stairs) for evacuation in emergencies can affect the emergency management and efficiency of emergency evacuation.

In emergency response of subway systems, the selection of appropriate strategies for emergency evacuation and accurate evacuee guidance strategies is essential. Evacuation and accurate evacuee guidance strategies are also essential in other types of incidents. The results of a case study indicated that, if the entrance passage of relief forces to the station is blocked, the process of relief will be delayed. Therefore, guided evacuation can reduce the number of deaths in terrorist or chemical attacks. Identification of alternative evacuation paths and selection of appropriate station evacuation strategies in responding to emergency situations, exit selection strategy, or appropriate use of any available exit can greatly improve the efficiency of evacuation.

Other factors contributing to the safe evacuation of passengers determining their response to emergencies including the identification of airflow conditions inside the system, smoke evacuation, controlling smoke spread, selecting strategies for station and tunnel ventilation, and using evacuation methods (e.g., elevators or not) are subjects related to the type of response to emergency situations, which are significant in effective evacuation with minimum injuries to the crowd in subway stations. Decision-making for evacuation in emergencies is vital and completely different from evacuation in normal situations. In emergencies, the passengers’ decision in selecting various paths highly affects evacuation duration. Therefore, in addition to decision-making in a short time, optimal decision-making, i.e., selecting the shortest uncrowded path, is essential.

Other studies also indicated on the critical status for decision-making in the case of hospital emergency evacuation decision-making and suggest for decision support systems. It seems that subway evacuation decision support system can also be taken into account for better and timely decision. In some studies included in the present systematic review also, decision-making for response operations and decision support and emergency notification systems were identified as factors affecting a timely evacuation response.

In some studies of the current systematic review, researchers identified the management of evacuees exiting the station and management of buses when urban rail transportation operations are stopped to be necessary for the subway station emergency evacuation process; it would be possible to control the traffic of evacuees to confront exit blockage and threats related to crowd aggregation outside the stations if bus transportation outside the train is ready. Based on the results of these studies, our findings conclude that the spectrum of definition of a safe emergency evacuation can be expanded from the time of the public announcement of emergency evacuation until the distribution and transfer of evacuees outside the subway station to the street.

In general, in places such as subway stations faced with crowd aggregation, there is the risk of secondary incidents such as crowd disaster following by emergency situation. Therefore, in response to emergency situations, emergency management simultaneous with crowd management has special importance. In an efficient management of emergencies and disasters, the activation of an incident command system (ICS) is an effective strategy for responding to emergency situation and disasters; however, based on the present systematic review findings, lack of studies related to efficiency and importance of ICS in response of subway emergency evacuation is evident. Thus, in the field of ICS efficiency in subway incident management and emergency response, future studies can discuss more.

**Reconstruction and maintenance of evacuation facilities**

Other factors related to subway station management, which affect the management of safe evacuation during emergencies, include the reconstruction and maintenance of evacuation equipment and facilities, telecommunication equipment, and relief and rescue facilities in stations. Consequently, it is important to perform reconstruction, maintenance, and updating programs for subway rail transportation system, in
order to ensure the timely functioning of equipment during emergencies. This is also in line with previous studies in injury prevention fields, which pronounced the importance of evacuation facility, of which mainly related to a system approach for injury and accident prevention.[212]

**Conclusion**

This systematic review showed that there is a lack of system approach in literatures. Furthermore, the number of studies on subway emergency evacuation with a qualitative and health-based approach is very low.

Most studies in the present systematic review focused on evacuation in the shortest possible time in order to mitigate injuries and causalities during emergencies and disasters. The dominant approach of studies to analyze the efficiency of emergency evacuation was quantitative approach; there is a lack of qualitative approach to effectiveness of subway emergency evacuation by focusing on minimizing injuries during evacuations. Therefore, it is essential to review safe evacuation indicators in future qualitative studies with focus on human health in emergencies.

As a result of systematic literature review of studies on system approach to safe emergency evacuation in subways, we found the considering optimal egress paths for emergency evacuation as the main theme of environmental factors. As well as, the mitigation of injuries and preparedness are initial proceeding for successful emergency evacuation as organizational management-related factors effect on safe emergency evacuation.

Based on the evidence of the present systematic review, environmental factors can affect efficiency of emergency evacuation through modifying safe egress time. On the other hand, preventive and preparedness measures are organizational management-related factors often taken to increase the ASET. The results of the present study also confirm organizational actions and environmental measures that can be taken to improve the safe egress time. Consequently, from the researcher’s point of view, the timely decision-making for responding to emergency situations, such as decision-making for emergency evacuation public announcing and passenger’s timely reactions to evacuation alarm and decision to start evacuation, can almost save the ASET before the accident turns into a crisis and can prevent injuries and causalities.

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**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Tan J, Wang T, Chen Y, Bai G, editors. Safety evacuation measures in urban subway fire. 2009 2nd International Conference on Intelligent Computing Technology and Automation; 2009.
2. Abu-Zaid SA. Analyzing a transit subway station during fire emergency using computational fluid dynamics. Transp Res Rec 1996;1521:159-64.
3. Tajedi NA, Sukur SA, Ismail SM, Isa HA. Analysing the simulation model of risk perception based of the pedestrian behaviour at underground station in Malaysia: A framework paper. ARPN J Eng Appl Sci 2016;11:5409-12.
4. Jiang CS, Deng YF, Hu C, Ding H, Chow WK. Crowding in platform staircases of a subway station in China during rush hours. Safety Sci 2009;47:931-8.
5. Landow HT, editor. Safe egress from deep stations. 47th Annual Transportation Research Forum; 2006.
6. Li YF, Chen JM, Ji J, Zhang Y, Sun JH, editors. Analysis of Crowded Degree of Emergency Evacuation at “bottleneck” Position in Subway Station based on Stairway Level of Service. Procedia Eng 2011;11:242-51.
7. Yang XX, Dong HR, Yao XM, Sun XB. Pedestrian evacuation at the subway station under fire. Chinese Physics B. 2016;25:048902.
8. Li D, Han B. Behavioral effect on pedestrian evacuation simulation using cellular automata. Saf Sci 2015;80:41-55.
9. Wu Y, Xu J, Jia L, Qin Y. Estimation of emergency evacuation capacity for subway stations. J Transp Saf Secur 2018;10:586-601.
10. Galea ER, Wang Z, Jia F, Lawrence PJ, Ewer J. Fire safety assessment of Open Wide Gangway underground trains in tunnels using coupled fire and evacuation simulation. Fire Mater 2017;41:716-37.
11. Nie HJ. Study on Safety Egress in Subway Fire. Ann Arbor: Northeastern University (People’s Republic of China); 2008.
12. Yang KH, Lee SK. Smoke management and egress design analysis of an underground railway station. J Appl Fire Sci 1999;9:153-71.
13. Shokouhi M, Nasiriani K, Cheraghiz Z, Ardalian A, Khankeh H, Fallahzadeh H, et al. Preventive measures for fire-related injuries and their risk factors in residential buildings: A systematic review. J Inj Violence Res 2019;11:1-14.
14. Sacfung A, Sookhanaphibarn K, Choensawat W. Serious Game for Fire Safety Evacuation Plan. Pedagogy. 2014;87:12.50.
15. Jeon G, Hong W. Characteristic features of the behavior and perception of evacuees from the Daegu subway fire and safety measures in an underground fire. J Asian Archit Building Eng 2009;8:415-22.
16. Li F, Chen S, Wang X, Feng F. Pedestrian evacuation modeling and simulation on metro platforms considering panic impacts. Procedia Soc Behav Sci 2014;138:14-22.
17. Zhang G, Huang D, Zhu G, Yuan G. Probabilistic model for safe evacuation under the effect of uncertain factors in fire. Saf Sci 2017;93:222-9.
18. Yuan Z, Jia H, Liao M, Zhang L, Feng Y, Tian G. Simulation model of self-organizing pedestrian movement considering following behavior. Front Information Technol Electron Eng 2017;18:1142-50.
19. Fang Z, Li Q, Li Q, Han LD, Wang D. A proposed pedestrian waiting-time model for improving space–time use efficiency in stadium evacuation scenarios. Build Environ 2011;46:1774-84.
20. Wang P, Luh PB, Chang S-C, Marsh KL, editors. Efficient optimization of building emergency evacuation considering social bond of evacuees. CASE. 2009.
21. Ma JC, Li J, Zhou XY. Reliability analysis of evacuees’ evacuation safety in fire based on the computer simulation method. J Disaster Prev Mitig Eng 2009;29:376-81.
22. Maguire M, Delahunt B. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. All Irel J Teach Learn Higher Educ 2017;9:3351-9.
23. Ma L, Chen B, Qiu S, Li Z, Qiu X. Agent-based modeling of emergency evacuation in a railway station square under sarin terrorist attack. International Journal of Modeling, Simulation, and Scientific Computing. 2017;8(02):1750022.
24. Tsukahara M, Koshiba Y, Ohtani H. Effectiveness of downward evacuation in a large-scale subway fire using Fire dynamics simulator. Tunnelling Underground Space Technol 2011;26:573-81.
25. Jevtic RB. Security in metro-an example for simulation of evacuation from subway. Facta Universitatis, Series: Working and Living Environmental Protection; 2017.p. 197-208.
26. Hu QM, Fang WN, Li GY, Ding L. Influence of exit layout of a metro
station on pedestrian evacuation. J China Railway Soc 2009;31:111-5.
27. Qu Y, Dan Y. Modeling the evacuation behavior considering the effect of
dangerous source. Procedia Soc Behav Sci 2014;138:800-10.
28. Jiang CS, Ling Y, Hu C, Yang Z, Ding H, Chow WK. Numerical
simulation of emergency evacuation of a subway station: A case study
in Beijing. Archit Sci Rev 2009;52:183-93.
29. Ma J, Wang R, Qiu Q. Passenger assignment model for emergency
evacuation in metro rail tunnels. J China Railway Soc 2016;38:8-14.
30. Zheng Y, Jia B, Li XG, Jiang R. Evacuation dynamics considering
pedestrians’ movement behavior change with fire and smoke spreading.
Saf Sci 2017;92:180-9.
31. Lei W, Li A, Gao R, Hao X, Deng B. Simulation of pedestrian crowds’
evacuation in a huge transit terminal subway station. Physica A
2012;391:5355-65.
32. Yue H, Wang S, Zhang L, Shao C. Setting method of emergency exits
in pedestrian walking facilities. J Beijing Jiaotong Univ 2014;38:1-6.
33. Zhang LM, Liu MJ, Wu XG, Abou Rizk SM. Simulation-based route
planning for pedestrian evacuation in metro stations: A case study.
Autom Constr 2016;71:430-42.
34. Yao H, Zhao Z, Li Y, Liang D. Matching design of bottlenecks in the
emergency evacuation of metro station. J of Residuals Sci Technol
2016;13:551-5.
35. Wang H, Wang ZY, Hu YX, Liu LK. Simulation research based on
 evacuation ability estimation method. Proceedings of the 2016 12th
World Congress on Intelligent Control and Automation (Wcica),
IEEE; 2016.6:645-9.
36. Fridolf K, Nilsson D, Frantzich H. The flow rate of people during train
evacuation in rail tunnels: Effects of different train exit configurations.
Saf Sci 2014;62:515-29.
37. Chen YZ, Cai SJ, Deng YF. Simulation Study on Main Affect Factors
to the Evacuation Corridor. Applied Mechanics and Materials.
2012;170:3533-8.2.
38. Shi C, Zhong M, Liu Z, editors. Reliability analysis on occupant
evacuation of elevated metro station in fires. 9th International Conference
on Probabilistic Safety Assessment and Management 2008; 2008.
39. Zhang X, Xu J, Guo JY, Wang Y, editors. Study on evacuation facilities
bottleneck in xizhimen station with simulation. Advanced Materials
Research. Switzerland: Trans Tech Publ; 2013; 706-708: 2044-7.
40. Erkan İ, Hastemoglu H. Building evacuate module for urban underground
passages: Subway station in Turkey. J Transp Technol 2015;5:1.
41. Wang QQ, Du YY, Zhang XY. Application of ant colony algorithm
in subway station emergency evacuation. Fire Sci Technol 2015;1:22.
42. Yileng W. Virtual assessment model on emergency evacuation capacity
of Beijing subway based on BP neural network algorithm. J Saf Sci
Technol 2012;1:5-10.
43. Xiaoqiao Z, Xueying Y. Study on safety evacuation time for passengers
in subway station and its application. Advanced Materials Research. ???:
Switzerland; 2013. p. 2965-9.
44. Li ZJ. Evacuation time of the facilities in rail transit study and simulation.
Applied Mechanics and Materials. Switzerland: 2013. p. 1137-40.
45. Xu, Yan Ying Duan, Wan Wan Li, Lu Chao. "Safety Evacuation at Metro
Transit Station in Shenyang under Fire", Advanced Materials Research,
Vols. 864-867, pp. 849-852, 2014.
46. Li C, Li J. Simulation and Analysis of the Crowd Evacuation in Subway
Station. ICTE; 2015. p. 2394-400.
47. Dezhi Z. Safety evacuation design for the entrances and exits of deep
stations on chongqing metro. Urban Rapid Rail Transit 2009;2:24.
48. Okada N, Hasemi Y, Moriyama S. Feasibility of upward evacuation by
escalator – An experimental study. Fire Mater 2012;36:429-40.
49. Cheng H, Yang X. Emergency evacuation capacity of subway stations.
Procedia Soc Behav Sci 2012;43:339-48.
50. Chen YY, Cai YW, Li PP, Zhang GH. Study on evacuation evaluation in
subway fire based on pedestrian simulation technology. Math Probl Eng
2015;http://dx.doi.org/10.1155/2015/357945:9.
51. Butler K, Kuligowski E, Furman S, Peacock R. Perspectives of
occupants with mobility impairments on evacuation methods for use
during fire emergencies. Fire Saf J 2017;91:955-63.
52. Wu XC, Xie D, Li L. An analysis on the occupants evacuation time
computation of the subway platform. J Shenyang Aerospace Univ
2012;5:18.
53. Wu J, Hu S, Feng J. Study on safe area in railway station under fire.
J Tongji Univ (Nat Sci) 2010;3:15.
54. Xie H, Xu YY, Zhang X, Chen J. Study on Emergency Evacuation
in the Subway Fire Accidents. Applied Mechanics and Materials.
2014;580:1033.
55. Li ZY, Tang M, Liang D, Zhao Z. Numerical simulation of evacuation in
a subway station. Procedia Engr 2016;135:616-21.
56. Chen SK, Di Y, Liu S, Wang BS. Modelling and analysis on emergency
evacuation from metro stations. Math Probl Engr 2017:11.
57. Hong L, Gao J, Zhu W. Simulating emergency evacuation at metro
stations: An approach based on thorough psychological analysis. Transp
Let 2016;8:113-20.
58. Liao YF, Ma XQ. Simulation of pedestrian dynamics under subway fire
using extended cellular automaton. J Syst Simul 2008;20:24.
59. Qu L, Chow WK. Platform screen doors on emergency evacuation in
underground railways stations. Tunnelling Underground Space Technol
2012;30:1-9.
60. Wu B, Wu ZS, Wang Z, Ji J, editors. Guangzhou: South China Univ
Technology Press; 2009. 1624-p.
61. Roh JS, Ryoo HS, Park WH, Jiang YJ. CFD simulation and assessment
of life safety in a subway train fire. Tunnelling Underground Space
Technol 2009;24:447-53.
62. Zhou H, He J, Jiang T, Tang X. Smoke diffusion and control at different
platform floor structure of subway station in fire. China Railway Sci
2008;29:126-31.
63. Roh JS, Ryoo HS, Yoon SW. The effect of PSD on life safety in subway
station fire. J Mech Sci Technol 2010;24:937-42.
64. Zhi-Yong L. Performance-based study on evacuation security of
ultra-long passageway in subway station department store. J Jiangxi
Instit Edu 2011;3:20.
65. Yang JT, Yang Y, Wang HL, Shi L. Effect of the open ways of screen
doors on fire smoke in a subway platform. Procedia Engineering.
2011;11:416-23.
66. Zhang P, Zhang S, Yu J. The impact of screen doors on smoke spread of
tunnel fire in island subway platform. J Shenyang Jianzhu Univ (Nat
Sci) 2007;23:794-7.
67. Chang S, Wu YS, Huang CJ, Chang KY. Effect of varied fire
compartment areas in mass rapid transit underground malls with FDS
simulation. J Appl Fire Sci 2007;17:261-78.
68. Moriyama S, Hasemi Y, Nam DG, Tanaka S, Okazawa N, Ding W.
Smoke movement characteristics and fire safety in subway stations.
Fire Saf Sci 2005;8:1461-72.
69. Zhou R, He J, Jiang J, editors. Effects of the PED on smoke control of subway
station fires. J China Railway Soc 2008;30:62-7.
70. Wang W, He T, Huang W, Ren R, Wang Q. Optimization of switch
modes of fully enclosed platform screen doors during emergency
platform fires in underground metro station. Tunnelling Underground
Space Technol 2018;81:277-88.
71. Yim K, editor. Fire evacuation simulation for the case of a non-symmetrical
metro station using Wireless Sensor Network. 2015 5th International
Conference on Information Science and Technology; 2015.
72. Yim K, Jiang J, editors. Application of fire monitoring and personnel
evacuation in subway station based on wireless sensor network. ICALEIP
2014-2014 International Conference on Audio, Language and Image
Processing.; 2015.
73. Yang P, Li C, Chen D. Fire emergency evacuation simulation based on
integrated fire-evacuation model with discrete design method. Adv Eng
Softw 2013;65:101-11.
74. Sarunac R, Hamilton BA, editors. A Safe Train State of Mind.
Proceedings of the ASME/IEEE/ASCE Joint Rail Conference, JRC;
2008.
75. Xin Han, Chong Yu Li, Bei Hua Cong. “CFD Analysis on Fire Feature of
Subway Station with Different Location of Ticket Machine”, Advanced
Materials Research. Vols. 864-867, pp. 849-852, 2014.
76. Li ZY, Tang M, Liang D, Zhao Z. Numerical simulation of evacuation in
a subway station. Procedia Engr 2016;135:616-21.
77. Chen SK, Di Y, Liu S, Wang BS. Modelling and analysis on emergency
evacuation from metro stations. Math Probl Engr 2017:11.
78. He LG, Shi CL, Zhong MH, Xu X. Analysis and discussion on passenger
evacuation by lateral emergency evacuation platform in metro tunnel.
J Saf Sci Technol 2013;7:10.
79. Liu FL, Wang YX, Zhou WT. Research on simulation of evacuation
in the deep buried station of urban rail transit. Applied Mechanics and Materials. Vol. 505. Switzerland 2014. p. 712.

79. Tachibana H. Public space acoustics for information and safety. The Journal of the Acoustical Society of America. 2013;133(5):35-80.

80. Li ZH, Zhang X, editors. Simulation and analysis based on emergency evacuation success rate in elevated layer of Beijing South railway station. Applied Mechanics and Materials. Switzerland: Trans Tech Publ; 2014.

81. Norén A, Winér J. Modelling Crowd Evacuation from Road and Train Tunnels-Data and Design for Faster Evacuations. LUTFVDG/TVBHH–5127–SE–2003.

82. Zhang B, Xu ZS, Zhao QW, Liu YY. A study on theoretical calculation method of subway safety evacuation. Procedia Eng 2014;71:597-604.

83. Liao M, Xie F, Liu J, Liu D, editors. The survey and study on pedestrian evacuation in beijing underground of subway-mall. Proceedings – 2013 4th International Conference on Digital Manufacturing and Automation. ICDMA; 2013.

84. Sun XB, Hong NR, Ning B, Gao TX, Kong QJ. ACP-based emergency evacuation system Acta Automatica Sinica 2014;40:16:23.

85. Xie J, He JP, Zhou R, Peng HP. Analysis of air curtain applied in subway station to prevent smoke. In: Li SC, Wang YJ, Huang P, editors. Analysis of air curtain applied in subway station to prevent smoke. Beijing: Science Press Beijing; 2005. p. 1143-6.

86. Luo H, Peng X, Zhong B, editors. Application of ontology in emergency plan management of metro operation. Procedia Eng 2016;164:158-65.

87. Zhou Y, Zhou L, Yue Y. Research on Subway Station Emergency Evacuation Network Conformation and Application Based on Blocking Flow Theory. XJTU Academic Hub. 2005;22:1-12.

88. Lin-Na C. Research on subway station fire emergency evacuation simulation based on multi-stress. J Wuwei Univ (Nat Sci Ed) 2016;1:7.

89. Zhong MH, Shi CL, Tu XW, Fu TR, He L. Study of the human evacuation simulation of metro fire safety analysis in China. J Loss Prev Process Ind 2008;21:287-98.

90. Jiang LC, Chen JT. Research on safety evacuation of large-scale railway passenger transport hub. Advanced Materials Research. Switzerland; 2014. p. 2095-100.

91. Wu J, Feng J, Chen X. Comparative study of subway station evacuation design of PR China and USA. J Tongji Univ (Nat Sci) 2009;8:8.

92. Papakonstantinou D, Benardos A, Kallianiotis A, Menegaki M. Analysis of the crowd evacuation modeling approaches for the case of urban underground spaces. Procedia Eng 2016;165:602-9.

93. Madinaveitia J. Safety systems in underground tunnels of the Bilbao underground space. Procedia Eng 2016;165:602-9.

94. Miclea PC, McKinney D, editors. Fire development, smoke control and engineering solutions for improving operational safety and efficiency of subways with two-way tunnels. Procedia Engineering. 2016;165:214-23.

95. Tong R, Wang B, Li J, Tang S, Zhang B, Tan Z. A risk-based approach for crowd evacuation performance evaluation under metro fire. Georisk 2015;9:75-95.

96. Chen SK, Di Y, Shi RD, Li J, Wang B. Simulation and analysis on impacts and evacuation during the process of fire on metro platforms. J Transp Syst Eng Inf Technol 2017;17:241-8.

97. Guo C, Wang M, Yu L. Control and behavior prediction of personnel evacuation in underground ventilation equipment room on fire. Applied Mechanics and Materials. Switzerland 2012. p. 2582-6.

98. Vittori F, Rojas-Solórzano L, Blanco AJ, Urbina R, editors. Numerical study of smoke propagation in a simulated fire in a wagon within a subway tunnel. 2008 Proceedings of the ASME Fluids Engineering Division Summer Conference, FEDSM 2008; 2009.

99. Zhao L. Numerical Simulation Study on Emergency Ventilation System in Subway Stations. Ann Arbor: Tianjin University (People’s Republic of China); 2008.

100. Rie DH, Yoon SW, Ko JW, Lee KO. Study on disaster prevention in case of fire at subway platform with platform screen door. Li SC, Wang YJ, Huang P, editors. Beijing: Science Press Beijing; 2005. 921-7 p.

101. Fridolf K, Nilsson D, Frantzich H. Evacuation of a metro train in an underground rail transportation system: Flow rate capacity of train exits, tunnel walking speeds and exit choice. Fire Technol 2016;52:1481-518.

102. Chen T, Zhang SY, Zhao LQ, Xia JX, Fu XC, Bao ZM, et al. Comparison of safety equipment between London underground and Beijing subway. IOP Conference Series: Earth and Environmental Science 2017.

103. Fridolf K, Ronchi E, Nilsson D, Frantzich H. Movement speed and exit choice in smoke-filled rail tunnels. Fire Saf J 2013;59:8-21.

104. Shirai T, Yamazaki T, Inoue K, Yokoi H. Improving accessibility for emergency evacuation signage in public space. Saf Sci 2017;91:132-47.

105. Motamedi A, Wang Z, Yabuki N, Fukuda T, Michikawa T. Signage visibility analysis and optimization system using BIM-enabled virtual reality (VR) environments. Adv Eng Inf 2017;32:248-62.

106. Hiroi U, Aoyama J. Study about the effect of the signposting for evacuation in the underground space. J Disaster Res 2016;11:315-21.

107. Song B, Chen F, Su JY. Optimization for the subway emergency evacuation system. J Beijing Univ Technol 2008;34:504-10.

108. Zhang Z, Jia LM, Qin Y. Optimization of signage system configuration on metro platform based on cooperative guidance. J Transp Syst Eng Inf Technol 2016;16:46-52.

109. Yue H, Shao CF, Guan HZ, Cui D. Location method of emergency evacuation signs in large pedestrian facilies. J Beijing Univ Technol 2013;39:914-9.

110. Zhang Z, Jia L, Qin Y. Optimal number and location planning of evacuation signage in public space. Saf Sci 2017;91:132-47.

111. Chen YX. Agent-based research on crowd interaction in emergency evacuation. Cluster Comput 2017;1-14. DOI: https://doi.org/10.1007/s1058

112. Xu X, Song B, Li C, Hu X, editors. Study on the safety and disaster-prevention signing system of the subway based on site investigation at home and abroad. Proceedings – International Conference on Management and Service Science. MASS; 2009.

113. Jia HF, Li YX, Yang LL, Zhou YN. Modeling the separating pedestrian evacuation in the underground space. J Disaster Res 2016;11:315-21.

114. Shao M, Maddahin B, Afsin H, Farhanie B, editors. Designing fire scenarios for subway stations and tunnels based on regional approach. Advanced Materials Research. Switzerland: Trans Tech Publ; 2012.; 433-44: 983-91

115. Gao R, Li AG, Lei WJ, Zhao YJ, Zhang Y, Deng BS. Study of a proposed tunnel evacuation passageway formed by opposite-double air curtain ventilation. Saf Sci 2012;50:1549-57.

116. Zhang Z, Qin Y, Cheng X, Zhi L, Kui L, Li J, et al., editors. Metro Station Safety Status Prediction Based on GA-SVR. Proceedings of the 2015 International Conference on Electrical and Information Technologies for Rail Transportation; 2016. Springer.

117. Maslak V, Boytsov D, Danilov A, Levina E, Gendler S. Innovative engineering solutions for improving operational safety and efficiency of subways with two-way tunnels. Procedia Engineering. 2016;165:214-23.

118. Tong R, Wang B, Li J, Tang S, Zhang B, Tan Z. A risk-based approach for crowd evacuation performance evaluation under metro fire. Georisk 2015;9:75-95.

119. Chen SK, Di Y, Shi RD, Li J, Wang B. Simulation and analysis on impacts and evacuation during the process of fire on metro platforms. J Transp Syst Eng Inf Technol 2017;17:241-8.
126. Chow WK, Ng CM. Waiting time in emergency evacuation of crowded public transport terminals. Saf Sci 2008;46:844-57.

127. Baysal Türkömez G, Güneş M. Metro servis sistemiinde acil tahlİYE modelleri: İzmir metro uygulaması. Pamukkale Univ J Eng Sci 2016;22:324-38.

128. Li YZ, Gong X, Chen CK. Study on the performance-based safe evacuation design in tunnel fires. J Disaster Prev Mitig Eng 2006;26:409-13.

129. Ceng S. Studies on Intelligent Evacuation Model based Simulation of Fire in Urban Underground Building. Ann Arbor: South China University of Technology (People’s Republic of China); 2009.

130. Li JF, Liu M, Sui XL, He WF. Simulation of available safe egress time in metro based on Monte Carlo method. In: Huang P, Wang Y, Li SC, Zheng C, Mao ZH, editors. Monmouth Junction: Science Press USA Inc.; 2006. p. 394-8.

131. Zeng S, Zha XX, Chen YY, Jiang RJ. Safe evacuation from subway station under platform train fire. Applied Mechanics and Materials. Switzerland 2014. p. 2025-6.

132. Wang WL, Jacqueline Lo TY. A simulation study on passenger escape in rail tunnels. Procedia Eng 2014;71:552-7.

133. Ronchi E. Testing the predictive capabilities of evacuation models for tunnel fire safety analysis. Saf Sci 2013;59:141-53.

134. Wang ZL, Hua M, Xu DY, Pan XH. Simulation research on human evacuation in subway with a single-point fire scenario. In: Changgen F, Shengcai L, editors. 2014 International Symposium on Safety Science and Technology. Procedia Engineering. 84. Amsterdam: Elsevier Science Bv; 2015. p. 595-602.

135. Lo S, Wang W, Liu S, Ma J. Using agent-based simulation model for studying fire escape process in metro stations. Procedia Comput Sci 2014;32:388-96.

136. Pfistsch A, Brueme M, Killing-Heinze M, Ringes J, Agnew B, Steiling B. Natural ventilation as a factor controlling the dispersal of airborne toxins in subway systems in a disaster situation. J Transp Saf Secur 2013;5:78-92.

137. Jiuhui W, Jie S, editors. Emergency evacuation in subway station based on Combined Social Force Model. ICEIEC 2013 – Proceedings of 2013 IEEE 4th International Conference on Electronics Information and Emergency Communication; 2013.

138. Nguyen MH, Ho TV, Zucker JD. Integration of smoke effect and blind evacuation strategy (SEBES) within fire evacuation simulation. Simul Model Pract Theory 2013;26:44-59.

139. Mao J, Lv H, Li SL, Li WJ. Smoke extraction function of mobile smoke ventilator in the fire scene of the subway station. J Beijing Jiaotong Univ 2007;31:128-30.

140. Li YF, Zhu B, Sun X, Li JM, Du XL. Study of fire smoke diffusion in subway tunnel by large eddy simulation. J Beijing Univ Technol 2007;33:1060-5.

141. Chen JH, Yang LB, Zhou ZY, Zhang ZF. Analogic-based emergency evacuation of pedestrians in underground fire. In: VandeWalle B, Li X, Zhang S, editors. China: Harbin: Harbin Engineering University, 2007. p. 17-23.

142. Haack A, Schreyer J, editors. Emergency scenarios for public commuter transportation tunnels. WIT Transactions on the Built Environment. 2005;8:122.

143. Jeon GY, Kim JY, Hong WH, Augenbroe G. Evacuation performance of individuals in different visibility conditions. Build Environ 2011;46:1094-103.

144. Wang C. Study on the Fire Smoke Control and Evacuation in the Subway Transfer Station. Ann Arbor: Beijing University of Technology (People’s Republic of China); 2011.

145. Wang X, Chen S, Zhou Y, Peng H, Cui Y, editors. Simulation on passenger evacuation under fire emergency in metro station. IEEE ICIRCT 2013 – Proceedings: IEEE International Conference on Intelligent Rail Transportation; 2013.

146. Liang H, Xu W. Performance analysis on evacuation in subway fire. J Shenyang Jianzhu Univ (Natl Sci) 2012;28:702-9.

147. Xie H, Xu YY, Zhang X, Chen J, editors. Study of life safety on the fire accidents in the subway station. Applied Mechanics and Materials. Switzerland: Trans Tech Publ; 2014;580-583:1029-32.

148. Wang Q, Wang W. Planning and countermeasures of emergency evacuation route in subway fire. J Saf Sci Technol 2017;13:1-14.

149. Chang HP, Ho SP, Chen CS, Shen TS. The evacuation safety analysis of fire scenarios in the entire acoustic barriers of elevated mass rapid transit system. Tunnelling Underground Space Technol 2016;56:65-9.

150. Li YF, Lin XX, Feng X, Wang C, Li JM. Life safety evacuation for cross interchangeable subway station. In: Changgen F, Shengcai L, editors. 2012 International symposium on safety science and technology. Procedia Engineering. 45. Amsterdam: Elsevier Science Bv; 2012. p. 741-7.

151. Cai Y, Lin ZY, Mao J, Bai G, Hu JW. Study on law of personnel evacuation in deep buried metro station based on the characteristics of fire smoke spreading. Procedia Eng 2016;135:544-50.

152. Ardalan A, Kandi Keleh M, Saberinia A, Khorasani-Zavareh D, Khankeh H, Miadfar J, et al. 2015 estimation of hospitals safety from disasters in I.R.Iran: The results from the assessment of 421 hospitals. PLoS One 2016;11:e0161542.

153. Hong L, Xu RH, editors. Analysis on Game Behaviors of Passengers in Emergency Evacuation in Subway Station. Applied Mechanics and Materials. Switzerland: Trans Tech Publ; 2011;97-98:576-82.

154. Marsella S, Delpiato U, Marzoli M, editors. Save Me Project: Improving safety of transportation using innovative technologies. Reliability, Risk and Safety: Back to the Future. Rome, Italy; 2010.

155. Xie J, He JP, Zhang Y. Fuzzy synthesis assessment analysis of safety evacuation in subway station fire. In: Huang P, Wang Y, Li SC, Zheng C, Mao ZH, editors. Fuzzy synthesis assessment analysis of safety evacuation in subway station fire. Monmouth Junction: Science Press USA Inc.; 2006. p. 338-41.

156. Tian JR, Zhou XQ. Analysis on people evacuation in a subway fire. Fire Sci Technol 2011;30:1011-4.

157. Qian Q, Lin P. Safety risk management of underground engineering in China: Progress, challenges and strategies. J Rock Mech Geotech Eng 2016;8:423-42.

158. Tokunaga T, Amano K, Oiwa D, Uchiyama S, Mizuno M, Ohmiya Y, et al. An experimental study on the smoke behavior and ensuring the safety of staircases in a station building during a fire – Air current control in an underground station by a passive safety system. Fire Sci Technol 2007;26:9-42.

159. Shi WB. Study on Fire Risk Assessment and Human Evacuation of Subway Stations. Ann Arbor: Beijing University of Technology (People’s Republic of China); 2008.

160. Yaghoubi T, Ardalan A, Khorasani Zavareh D, Khankeh H, Nejati A, Ebadi A. Decision-making on hospital emergency evacuation in disasters and emergencies: Findings from a systematic review. Iran Red Crescent Med J 2017;19:e4214.

161. Lu K, Han B. Congestion risk evaluation and precaution of passenger flow in metro stations. Open Civil Eng J 2016;10:93-104.

162. Nguyen MH, Ho TV, Nguyen TN, Zucker JD, editors. Which Behavior is best in a Fire Evacuation: Simulation with the Metro supermarket in Emergency Evacuation in Subway Station. Ann Arbor: Science Press USA Inc.; 2012.

163. Haack A, Schreyer J. Emergency scenarios for tunnels and underground stations in public transport. Tunnelling and Underground Space Technology. 2006;21(3-4):203-9.

164. Zhang P, Zhang Y, Zhan H, Liu J. The application of human evacuation prediction platform in deep-buried subway station. J Shenyang Jianzhu Univ (Natl Sci) 2009;6:25.

165. Ishigaki T, Kawanaka R, Onishi Y, Shimada H, Toda K, Baba Y, editors. Assessment of safety on evacuating route during underground flooding. Advances in Water Resources and Hydraulic Engineering – Proceedings of 16th IAHR-APD Congress and 3rd Symposium of IAHR-ISHS; 2009.

166. He JF, Liu X. A subway emergency evacuation routing optimization method based on congestion degree. China Saf Sci J 2013;23:166-71.

167. Castle CJ, Longley PA. A GIS-Based Spatial Decision Support System for Emergency Services: London’s King’s Cross St. Pancras Underground Station. Geo-information for Disaster Management. Springer, Berlin, Heidelberg 2005. p. 867-81.

168. Ye QW, Lv YB, editors. Study on emergency evacuation strategies for unexpected large passenger flow in urban rail transit station. Material
211. Lindell M, Perry R, Prater C. Organizing response to disasters with the incident command system/incident management system (ICS/IMS). Int Workshop Emerg Response Rescue 2005;1-14.

212. Khorasani-Zavareh D. System versus traditional approach in road traffic injury prevention: A call for action. J Inj Violence Res 2011;3:61.

213. Sciences ECoSBUoM. official letter. Shahid Beheshti University of Medical Sciences. Tehran, Iran; 15 September, 2017.
Appendix 1a: Search syntax tables for systematic review on environmental and organizational management-related factors that affect the safe emergency evacuation in subway stations

| Search round | Syntax | Description | NNR | Records number |
|--------------|--------|-------------|-----|---------------|
| 1            | (ALL (Evacuation) OR ALL("emergency evacuation") OR ALL("Passenger flow") OR ALL("Passenger evacuation") OR ALL("Evacuation capability") OR ALL("Evacuation capacity") OR ALL("Evacuation plan") OR ALL("Evacuation strategy") OR ALL("Evacuation strategies") OR ALL("Evacuation route") OR ALL("Evacuation safety") OR ALL("Evacuation efficiency") OR ALL("Crowd evacuation") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation analysis") OR ALL("Evacuation facilities") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") OR ALL("Evacuation performance") OR ALL(" evacuation time") OR ALL(" evacuation process") OR ALL(" safe evacuation") OR ALL("passenger evacuation") OR ALL("human evacuation") OR ALL("humans evacuation") OR ALL("personnel evacuation") OR ALL("passengers evacuation") OR ALL("evacuation centers") OR ALL("evacuation center") OR ALL("safety evacuation") OR ALL("Fire evacuation") OR ALL("evacuation design") OR ALL("Safety evacuation") AND (ALL("subway stations") OR ALL("rail roads") OR ALL("subway station") OR ALL("subway fire") OR ALL("Metro") OR ALL("Urban rail") OR ALL("Urban transit") OR ALL("Urban station") OR ALL("Subway accidents") OR ALL("Underground station") OR ALL("Subway fire") OR ALL("Railway stations") OR ALL("Underground stations") OR ALL("Crowded subway") OR ALL("Metro stations") OR ALL("Metro station") OR ALL("Subway- mall") OR ALL("Underpass") OR ALL("Subway lines") OR ALL(Metropolitan) OR ALL(Metropolitan area) OR ALL("Underground area") OR ALL("Rail transit") AND (ALL("managerial factors") OR ALL("managerial requirements") OR ALL("administrative requirements") OR ALL("administrative factors") OR ALL("managerial") OR ALL("administrative") OR ALL("management factors") OR ALL("governance factors") OR ALL("critical governance factors") OR ALL("Safety management") AND (PUBYEAR <2019 AND PUBYEAR >1989) ALL("Evacuation strategies") OR ALL("Evacuation routes") OR ALL("Evacuation efficiency") OR ALL("Crowd evacuation") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation facilities") OR ALL("Evacuation efficacy") OR ALL("Evacuation time") OR ALL("Evacuation process") OR ALL("Evacuation analysis") OR ALL("Evacuation scenarios") OR ALL("Evacuation management") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") OR ALL("Evacuation performance") OR ALL(" evacuation time") OR ALL(" evacuation process") OR ALL(" safe evacuation") OR ALL("passenger evacuation") OR ALL("human evacuation") OR ALL("humans evacuation") OR ALL("personnel evacuation") OR ALL("passengers evacuation") OR ALL("evacuation centers") OR ALL("evacuation center") OR ALL("safety evacuation") OR ALL("Fire evacuation") OR ALL("evacuation design") OR ALL("Safety evacuation") AND (ALL("subway stations") OR ALL("rail roads") OR ALL("subway station") OR ALL("subway fire") OR ALL("Metro") OR ALL("Urban rail") OR ALL("Urban transit") OR ALL("Urban station") OR ALL("Subway accidents") OR ALL("Underground station") OR ALL("Subway fire") OR ALL("Railway stations") OR ALL("Underground stations") OR ALL("Crowded subway") OR ALL("Metro stations") OR ALL("Metro station") OR ALL("Subway- mall") OR ALL("Underpass") OR ALL("Subway lines") OR ALL(Metropolitan) OR ALL(Metropolitan area) OR ALL("Underground area") OR ALL("Rail transit") AND (ALL("managerial factors") OR ALL("managerial requirements") OR ALL("administrative requirements") OR ALL("administrative factors") OR ALL("managerial") OR ALL("administrative") OR ALL("management factors") OR ALL("governance factors") OR ALL("critical governance factors") OR ALL("Safety management") AND (PUBYEAR <2019 AND PUBYEAR >1989) ALL("Evacuation strategies") OR ALL("Evacuation routes") OR ALL("Evacuation efficiency") OR ALL("Crowd evacuation") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation facilities") OR ALL("Evacuation efficacy") OR ALL("Evacuation time") OR ALL("Evacuation process") OR ALL("Evacuation analysis") OR ALL("Evacuation scenarios") OR ALL("Evacuation management") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") OR ALL("Evacuation performance") OR ALL(" evacuation time") OR ALL(" evacuation process") OR ALL(" safe evacuation") OR ALL("passenger evacuation") OR ALL("human evacuation") OR ALL("humans evacuation") OR ALL("personnel evacuation") OR ALL("passengers evacuation") OR ALL("evacuation centers") OR ALL("evacuation center") OR ALL("safety evacuation") OR ALL("Fire evacuation") OR ALL("evacuation design") OR ALL("Safety evacuation") AND (ALL("subway stations") OR ALL("rail roads") OR ALL("subway station") OR ALL("subway fire") OR ALL("Metro") OR ALL("Urban rail") OR ALL("Urban transit") OR ALL("Urban station") OR ALL("Subway accidents") OR ALL("Underground station") OR ALL("Subway fire") OR ALL("Railway stations") OR ALL("Underground stations") OR ALL("Crowded subway") OR ALL("Metro stations") OR ALL("Metro station") OR ALL("Subway- mall") OR ALL("Underpass") OR ALL("Subway lines") OR ALL(Metropolitan) OR ALL(Metropolitan area) OR ALL("Underground area") OR ALL("Rail transit") AND (ALL("managerial factors") OR ALL("managerial requirements") OR ALL("administrative requirements") OR ALL("administrative factors") OR ALL("managerial") OR ALL("administrative") OR ALL("management factors") OR ALL("governance factors") OR ALL("critical governance factors") OR ALL("Safety management") AND (PUBYEAR <2019 AND PUBYEAR >1989) ALL("Evacuation strategies") OR ALL("Evacuation routes") OR ALL("Evacuation efficiency") OR ALL("Crowd evacuation") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation facilities") OR ALL("Evacuation efficacy") OR ALL("Evacuation time") OR ALL("Evacuation process") OR ALL("Evacuation analysis") OR ALL("Evacuation scenarios") OR ALL("Evacuation management") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") | Journals articles | ~25 | 247 |
| 2            | ALL("Evacuation features") OR ALL("Evacuation analysis") OR ALL("Evacuation facilities") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenarios") OR ALL("Evacuation management") OR ALL("Evacuation routes") OR ALL("Evacuation efficiency") OR ALL("Evacuation time") OR ALL("Evacuation process") OR ALL("Evacuation analysis") OR ALL("Evacuation scenarios") OR ALL("Evacuation management") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") | Conferences papers/conferences proceedings | ~16 | 117 |
### 1. Search syntax in Web of Science for managerial factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax                                                                 | Description                                                                 | NNR | Records number |
|---------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----|----------------|
| 1             | (TS=(Evacuation) OR TS=("emergency evacuation") OR TS=("Pedestrian evacuation") OR TS=("Passenger evacuation") OR TS=("Evacuation plan") OR TS=("Evacuation strategy") OR TS=("Evacuation capabilities") OR TS=("Evacuation safety") OR TS=("Evacuation efficiency") OR TS=("Crowd evacuation") OR TS=("Evacuation performance") OR TS=("Evacuation times") OR TS=("Evacuation behavior") OR TS=("Evacuation parameter") OR TS=("Evacuation features") OR TS=("Evacuation analysis") OR TS=("Evacuation facilities") OR TS=("Evacuation possibilities") OR TS=("Possible evacuation") OR TS=("Evacuation situation") OR TS=("Evacuation techniques") OR TS=("Evacuation scenario") OR TS=("Staged evacuation") OR TS=("Evacuation models") OR TS=("Evacuation performance") OR TS=("Evacuation time") OR TS=("Evacuation process") OR TS=("Safe evacuation") OR TS=("Passenger evacuation") OR TS=("Human evacuation") OR TS=("Humans evacuation") OR TS=("Personnel evacuation") OR TS=("Passengers evacuation") OR TS=("Evacuation centers") OR TS=("Evacuation center") OR TS=("Safety evacuation") OR TS=("Fire evacuation") OR TS=("Evacuation design") OR TS=("Safely evacuation") AND (TS=("subway stations") OR TS=("rail roads") OR TS=("subway station") OR TS=("subway fire") OR TS=("Metro") OR TS=("Urban rail") OR TS=("Urban transit") OR TS=("Urban station") OR TS=("Subway station") OR TS=("Subway accidents") OR TS=("subway incidents") OR TS=("subway events") OR TS=("Underground station") OR TS=("Subway fire") OR TS=("Metro station") OR TS=("Subway- mall") OR TS=("Underpass") OR TS=("Subway lines") OR TS=("Metropolitan") OR TS=("Metropolitan area") OR TS=("Underground area") OR TS=("Railway stations") OR TS=("Underground fire") OR TS=("Railway stations") OR TS=("Underground stations") OR TS=("Crowded subway") OR TS=("Metro stations") OR TS=("Subway stations") OR TS=("subway") OR TS=("rail road") OR TS=("rail road") OR TS=("subway") OR TS=("accident") AND (TS=("managerial factors") OR TS=("managerial requirements") OR TS=("administrative requirements") OR TS=("managerial factors") OR TS=("administrative requirements") OR TS=("goverance factors") OR TS=("critical governance factors") OR TS=("Safety management") AND (PUBYEAR <2019 AND PUBYEAR >1989) | 8   | 137            |

### 2. Search syntax in Web of Science for managerial factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax                                                                 | Description                                                                 | Records number |
|---------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------|
| 1             | (TS=(Evacuation) OR TS=("emergency evacuation") OR TS=("Pedestrian evacuation") OR TS=("Passenger evacuation") OR TS=("Evacuation plan") OR TS=("Evacuation strategy") OR TS=("Evacuation capabilities") OR TS=("Evacuation safety") OR TS=("Evacuation efficiency") OR TS=("Crowd evacuation") OR TS=("Evacuation performance") OR TS=("Evacuation times") OR TS=("Evacuation behavior") OR TS=("Evacuation parameter") OR TS=("Evacuation features") OR TS=("Evacuation analysis") OR TS=("Evacuation facilities") OR TS=("Evacuation possibilities") OR TS=("Possible evacuation") OR TS=("Evacuation situation") OR TS=("Evacuation techniques") OR TS=("Evacuation scenario") OR TS=("Staged evacuation") OR TS=("Evacuation models") OR TS=("Evacuation performance") OR TS=("Evacuation time") OR TS=("Evacuation process") OR TS=("Safe evacuation") OR TS=("Passenger evacuation") OR TS=("Human evacuation") OR TS=("Humans evacuation") OR TS=("Personnel evacuation") OR TS=("Passengers evacuation") OR TS=("Evacuation centers") OR TS=("Evacuation center") OR TS=("Safety evacuation") OR TS=("Fire evacuation") OR TS=("Evacuation design") OR TS=("Safely evacuation") AND (TS=("subway stations") OR TS=("rail roads") OR TS=("subway station") OR TS=("subway fire") OR TS=("Metro") OR TS=("Urban rail") OR TS=("Urban transit") OR TS=("Urban station") OR TS=("Subway station") OR TS=("Subway accidents") OR TS=("subway incidents") OR TS=("subway events") OR TS=("Underground station") OR TS=("Subway fire") OR TS=("Metro station") OR TS=("Subway- mall") OR TS=("Underpass") OR TS=("Subway lines") OR TS=("Metropolitan") OR TS=("Metropolitan area") OR TS=("Underground area") OR TS=("Railway stations") OR TS=("Underground fire") OR TS=("Railway stations") OR TS=("Underground stations") OR TS=("Crowded subway") OR TS=("Metro stations") OR TS=("Subway stations") OR TS=("subway") OR TS=("rail road") OR TS=("rail road") OR TS=("subway") OR TS=("accident") AND (TS=("managerial factors") OR TS=("managerial requirements") OR TS=("administrative requirements") OR TS=("managerial factors") OR TS=("administrative requirements") OR TS=("goverance factors") OR TS=("critical governance factors") OR TS=("Safety management") AND (PUBYEAR <2019 AND PUBYEAR >1989) | 137 | 137            |
3. Search in PubMed for managerial factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax                                                                 | Description | Records number |
|---------------|------------------------------------------------------------------------|-------------|----------------|
| 1             | ((Evacuation) OR (“emergency evacuation”) OR (“Pedestrian evacuation” OR (“Passenger flow”) OR (“Passenger evacuation”) OR (“Evacuation capability”) OR (“Evacuation capacity”)) OR (“Evacuation plan”) OR (“Evacuation strategy”) OR (“Evacuation strategies”) OR (“Evacuation route”) OR (“Evacuation safety”) OR (“Evacuation efficiency”) OR (“Crowd evacuation”) OR (“Evacuation performance”) OR (“Evacuation times”) OR (“Evacuation behavior”) OR (“Evacuation parameter”) OR (“Evacuation features”) OR (“Evacuation analysis”) OR (“Evacuation facilities”) OR (“Evacuation possibilities”) OR (“Possible evacuation”) OR (“Evacuation situation”) OR (“Evacuation techniques”) OR (“Evacuation scenario”) OR (“Staged evacuation”) OR (“Evacuation models”) OR (“Evacuation performance”) OR (“evacuation time”) OR (“evacuation process”) OR (““safe evacuation”) OR (“passenger evacuation”) OR (“human evacuation”) OR (“humans evacuation”) OR (“personnel evacuation”) OR (“passengers evacuation”) OR (“evacuation centers”) OR (“evacuation center”) OR (“safety evacuation”) OR (“Fire evacuation”) OR (“evacuation design”) OR (“Safety evacuation”) AND (“subway stations”) OR (“rail roads”) OR (“subway station”) OR (“subway fire”) OR (“subway accidents”) OR (“subway incidents”) OR (“subway events”) OR (“Underground station”) OR (“Subway fire”) OR (“Railway stations”) OR (“Underground stations”) OR (“Crowded subway”) OR (“Metro stations”) OR (“Metro station”) OR (“Subway- mall”) OR (“Subway lines”) OR (“Metropolitan”) OR (“Metropolitan area”) OR (“Underground area”) OR (“Rail transit”) AND (“managerial factors”) OR (“managerial requirements”) OR (“administrative requirements”) OR (“governance factors”) OR (“critical governance factors”) OR (“safety evacuation”) AND 1990/01/01[PDAT] : 2019/01/20[PDAT] | 858 |
| 2             | ((Evacuation) OR (“emergency evacuation” [tiab]) OR (“Pedestrian evacuation” [tiab]) OR (“Passenger flow”) OR (“Passenger evacuation”) OR (“Evacuation capability”) OR (“Evacuation capacity”)) OR (“Evacuation plan”) OR (“Evacuation strategy”) OR (“Evacuation strategies”) OR (“Evacuation route”) OR (“Evacuation safety”) OR (“Evacuation efficiency”) OR (“Crowd evacuation”) OR (“Evacuation performance”) OR (“Evacuation times”) OR (“Evacuation behavior”) OR (“Evacuation parameter”) OR (“Evacuation features”) OR (“Evacuation analysis”) OR (“Evacuation facilities”) OR (“Evacuation possibilities”) OR (“Possible evacuation”) OR (“Evacuation situation”) OR (“Evacuation techniques”) OR (“Evacuation scenario”) OR (“Staged evacuation”) OR (“Evacuation models”) OR (“Evacuation performance”) OR (“evacuation time”) OR (“evacuation process”) OR (“safe evacuation”) OR (“passenger evacuation”) OR (“human evacuation”) OR (“humans evacuation”) OR (“personnel evacuation”) OR (“passengers evacuation”) OR (“evacuation centers”) OR (“evacuation center”) OR (“safety evacuation”) OR (“Fire evacuation”) OR (“evacuation design”) OR (“Safety evacuation”) AND (“subway stations” [tiab]) OR (“rail roads” [tiab]) OR (“subway station” [tiab]) OR (“subway fire” [tiab]) OR (“subway accidents” [tiab]) OR (“subway incidents” [tiab]) OR (“subway events” [tiab]) OR (“Underground station” [tiab]) OR (“Subway fire” [tiab]) OR (“Railway stations” [tiab]) OR (“Underground stations” [tiab]) OR (“Crowded subway” [tiab]) OR (“Metro stations” [tiab]) OR (“Metro station” [tiab]) OR (“Subway- mall” [tiab]) OR (“Subway lines” [tiab]) OR (“Metropolitan” [tiab]) OR (“Metropolitan area” [tiab]) OR (“Underground area” [tiab]) OR (“Rail transit” [tiab]) AND (“managerial factors” [tiab]) OR (“managerial requirements” [tiab]) OR (“administrative requirements” [tiab]) OR (“governance factors” [tiab]) OR (“critical governance factors” [tiab]) OR (“safety evacuation”) AND 1990/01/01[PDAT] : 2019/01/20[PDAT] | 132 |
4. Search syntax in ProQuest for managerial factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax                                                                 | Description                          | Records Number |
|---------------|------------------------------------------------------------------------|--------------------------------------|----------------|
| 1             | (ALL (Evacuation) OR ALL(“emergency evacuation”) OR ALL(“Passenger evacuation”) OR ALL(“Passenger flow”) OR ALL(“Passenger facilities”) OR ALL(“Passenger safety”) OR ALL(“Passenger route”) OR ALL(“Passenger strategy”) OR ALL(“Evacuation capability”) OR ALL(“Evacuation capacity”) OR ALL(“Evacuation plan”) OR ALL(“Evacuation safety”) OR ALL(“Evacuation strategy”) OR ALL(“Evacuation strategy”) OR ALL(“Evacuation analysis”) OR ALL(“Evacuation facilities”) OR ALL(“Evacuation possibilities”) OR ALL(“Possible evacuation”) OR ALL(“Evacuation situation”) OR ALL(“Evacuation techniques”) OR ALL(“Evacuation scenario”) OR ALL(“Staged evacuation”) OR ALL(“Evacuation models”)) OR ALL(“Evacuation performance”) OR ALL(“evacuation process”) OR ALL(“safe evacuation”) OR ALL(“passenger evacuation”) OR ALL(“human evacuation”) OR ALL(“humans evacuation”) OR ALL(“personnel evacuation”) OR ALL(“passengers evacuation”) OR ALL(“evacuation centers”) OR ALL(“evacuation center”) OR ALL(“safety evacuation”) OR ALL(“Fire evacuation”) OR ALL(“evacuation design”) OR ALL(“safely evacuation”) AND (ALL(“subway stations”) OR ALL(“rail roads”) OR ALL(“subway station”) OR ALL(“subway fire”) OR ALL(“Metro”) OR ALL(“Urban rail”) OR ALL(“Urban transit”) OR ALL(“Urban station”) OR ALL(“Subway”) OR ALL(“Subway accidents”) OR ALL(“Underground station”) OR ALL(“Subway fire”) OR ALL(“Railway stations”) OR ALL(“Underground stations”) OR ALL(“Crowded subway”) OR ALL(“Metro stations”) OR ALL(“Metro station”) OR ALL(“Subway- mall”) OR ALL(“Subway- Underpass”) OR ALL(“Subway lines”) OR ALL(“Metropolitan”) OR ALL(“Metropolitan area”) OR ALL(“Underground area”) OR ALL(“Rail transit”)) AND (ALL(“managerial factors”) OR ALL(“managerial requirements”) OR ALL(“adminastrative requirements”) OR ALL(“adminastrative factors”) OR ALL(“managerial”) OR ALL(“administrative”) OR ALL(“management factors”) OR ALL(“governance factors”) OR ALL(“critical governance factors”) OR ALL(“Safety management”)) AND YR (19900101-20190120) | Scholarly journals: 3 | Dissertations and theses: 6 | Feature: 3 | 9 |

Appendix 1b: Search syntax tables for systematic review on environmental factors affecting the safe emergency evacuation in subways

1. Search syntax in SCOPUS for environmental factors affecting the safe emergency evacuation in subways

| Search round | Syntax                                                                 | Description                          | NNR | Records number |
|--------------|------------------------------------------------------------------------|--------------------------------------|-----|----------------|
| 1            | (ALL (Evacuation) OR ALL(“emergency evacuation”) OR ALL(“Passenger evacuation”) OR ALL(“Passenger flow”) OR ALL(“Passenger facilities”) OR ALL(“Passenger safety”) OR ALL(“Passenger route”) OR ALL(“Passenger strategy”) OR ALL(“Evacuation capability”) OR ALL(“Evacuation capacity”) OR ALL(“Evacuation plan”) OR ALL(“Evacuation safety”) OR ALL(“Evacuation strategy”) OR ALL(“Evacuation strategy”) OR ALL(“Evacuation analysis”) OR ALL(“Evacuation facilities”) OR ALL(“Evacuation possibilities”) OR ALL(“Possible evacuation”) OR ALL(“Evacuation situation”) OR ALL(“Evacuation techniques”) OR ALL(“Evacuation scenario”) OR ALL(“Staged evacuation”) OR ALL(“Evacuation models”)) OR ALL(“Evacuation performance”) OR ALL(“evacuation process”) OR ALL(“safe evacuation”) OR ALL(“passenger evacuation”) OR ALL(“human evacuation”) OR ALL(“humans evacuation”) OR ALL(“personnel evacuation”) OR ALL(“passengers evacuation”) OR ALL(“evacuation centers”) OR ALL(“evacuation center”) OR ALL(“safety evacuation”) OR ALL(“Fire evacuation”) OR ALL(“evacuation design”) OR ALL(“safely evacuation”) AND (ALL(“subway stations”) OR ALL(“rail roads”) OR ALL(“subway station”) OR ALL(“subway fire”) OR ALL(“Metro”) OR ALL(“Urban rail”) OR ALL(“Urban transit”) OR ALL(“Urban station”) OR ALL(“Subway”) OR ALL(“Subway accidents”) OR ALL(“Underground station”) OR ALL(“Subway fire”) OR ALL(“Railway stations”) OR ALL(“Underground stations”) OR ALL(“Crowded subway”) OR ALL(“Metro stations”) OR ALL(“Metro station”) OR ALL(“Subway- mall”) OR ALL(“Subway- Underpass”) OR ALL(“Subway lines”) OR ALL(“Metropolitan”) OR ALL(“Metropolitan area”) OR ALL(“Underground area”) OR ALL(“Rail transit”)) AND (ALL(“environmental factors”) OR ALL(“environmental requirements”) OR ALL(“environmental factor”) OR ALL(“environment”) OR ALL(“environmental factors”) OR ALL(“environmental requirements”) OR ALL(“environmental factor”) OR ALL(“environmental)) AND (PUBYEAR <2019 AND PUBYEAR >1989) | Journals articles | ~25 | 1822 |

Contd...
### 1. Contd...

| Search round | Syntax | Description | NNR | Records number |
|--------------|--------|-------------|-----|----------------|
| 2            | (ALL (evacuation) OR TITLE-ABS("emergency evacuation") OR TITLE-ABS("Pedestrian evacuation") OR ALL("Passenger flow") OR TITLE-ABS("Passenger evacuation") OR ALL("Evacuation capability") OR ALL("Evacuation capacity") OR ALL("Evacuation plan") OR ALL("Evacuation strategy") OR ALL("Evacuation strategies") OR ALL("Evacuation route") OR ALL("Evacuation safety") OR ALL("Evacuation efficiency") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation analysis") OR ALL("Evacuation facilities") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Staged evacuation") OR ALL("Evacuation models") OR ALL("Evacuation performance") OR ALL("evacuation time") OR ALL("evacuation process") OR ALL("safe evacuation") OR ALL("passenger evacuation") OR ALL("human evacuation") OR ALL("humans evacuation") OR ALL("personnel evacuation") OR ALL("passengers evacuation") OR ALL("evacuation centers") OR ALL("safety evacuation") OR ALL("Fire evacuation") OR ALL("evacuation design") OR ALL("Safely evacuation") AND (TITLE-ABS("subway stations") OR ALL("rail roads") OR TITLE-ABS("subway station") OR TITLE-ABS("subway fire") OR TITLE-ABS (metro) OR ALL("Urban rail") OR ALL("Urban transit") OR ALL("Urban station") OR TITLE-ABS (subway) OR TITLE-ABS("Subway accidents") OR TITLE-ABS("subway incidents") OR TITLE-ABS("subway events") OR ALL("underpass") OR ALL("Subway- and mall") OR ALL (subway- AND mall) OR ALL("Subway lines") OR ALL (metropolitan) OR ALL("Metropolitan area") OR TITLE-ABS("Underground area") OR ALL("Rail transit") AND (TITLE-ABS("environmental factors") OR TITLE-ABS("environmental requirements") OR TITLE-ABS("environments requirements") OR TITLE-ABS("environmental factor") OR TITLE-ABS (environmental) AND (PUBYEAR<2019 AND PUBYEAR>1989)) | Journal article: 138 | ~13 | 217 |
|              |        | Conference paper: 29 |     |                |
|              |        | Book: 25 |     |                |
|              |        | Review: 8 |     |                |
|              |        | Book chapter: 9 |     |                |
|              |        | Conference review: 6 |     |                |
|              |        | Article in press: 2 |     |                |

### 2. Search syntax in Web of Science for environmental factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax | Description | Records number |
|--------------|--------|-------------|----------------|
| 1            | (TS=(Evacuation) OR TS=("emergency evacuation") OR TS=("Pedestrian evacuation") OR TS=("Passenger flow") OR TS=("Passenger evacuation") OR TS=("Evacuation capability") OR TS=("Evacuation capacity") OR TS=("Evacuation plan") OR TS=("Evacuation strategy") OR TS=("Evacuation strategies") OR TS=("Evacuation route") OR TS=("Evacuation safety") OR TS=("Evacuation efficiency") OR TS=("Evacuation performance") OR TS=("Evacuation times") OR TS=("Evacuation behavior") OR TS=("Evacuation parameter") OR TS=("Evacuation features") OR TS=("Evacuation analysis") OR TS=("Evacuation facilities") OR TS=("Evacuation possibilities") OR TS=("Possible evacuation") OR TS=("Evacuation situation") OR TS=("Evacuation techniques") OR TS=("Evacuation scenario") OR TS=("Staged evacuation") OR TS=("Evacuation models") OR TS=("evacuation performance") OR TS=("evacuation time") OR TS=("evacuation process") OR TS=("safe evacuation") OR TS=("passenger evacuation") OR TS=("human evacuation") OR TS=("humans evacuation") OR TS=("personnel evacuation") OR TS=("passengers evacuation") OR TS=("evacuation centers") OR TS=("safety evacuation") OR TS=("Fire evacuation") OR TS=("evacuation design") OR TS=("Safely evacuation") AND (TS=("subway stations") OR TS=("subway station") OR TS=("subway fire") OR TS=("Metro") OR TS=("Urban rail") OR TS=("Urban transit") OR TS=("Subway") OR TS=("Subway accidents") OR TS=("Underground stations") OR TS=("Railway stations") OR TS=("Metro stations") OR TS=("Underpass") OR TS=("Rail transit") AND (TS=("environmental factors") OR TS=("environmental requirements") OR TS=("environments requirements") OR TS=("environmental factor") OR TS=("environmental") AND (PUBYEAR<2019 AND PUBYEAR>1989)) | | 22 |
3. Search in PubMed for environmental factors affecting the safe emergency evacuation in subways

| Syntax no | Syntax                                                                 | Description                                                                 | Records number |
|-----------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------|
| 1         | ((Evacuation) OR ("emergency evacuation") OR ("Pedestrian evacuation") OR ("Passenger flow") OR ("Passenger evacuation") OR ("Evacuation capability") OR ("Evacuation capacity") OR ("Evacuation plan") OR ("Evacuation strategy") OR ("Evacuation strategies") OR ("Evacuation route") OR ("Evacuation safety") OR ("Evacuation efficiency") OR ("Crowd evacuation") OR ("Evacuation performance") OR ("Evacuation times") OR ("Evacuation behaviors") OR ("Evacuation parameters") OR ("Evacuation features") OR ("Evacuation analysis") OR ("Evacuation facilities") OR ("Evacuation possibilities") OR ("Possible evacuation") OR ("Evacuation situation") OR ("Evacuation techniques") OR ("Evacuation scenario") OR ("Staged evacuation") OR ("Evacuation models") OR ("Evacuation performance") OR ("Evacuation time") OR ("evacuation process") OR ("safe evacuation") OR ("passenger evacuation") OR ("human evacuation") OR ("humans evacuation") OR ("personnel evacuation") OR ("passengers evacuation") OR ("evacuation centers") OR ("evacuation center") OR ("safety evacuation") OR ("Fire evacuation") OR ("evacuation design") OR ("Safely evacuation") AND (("subway stations") OR ("rail roads") OR ("subway station") OR ("subway fire") OR ("Metro") OR ("Urban rail") OR ("Urban transit") OR ("Urban station") OR ("Subway") OR ("Subway accidents") OR ("subway incidents") OR ("subway events") OR ("Underground station") OR ("Subway fire") OR ("Railway stations") OR ("Underground stations") OR ("Crowded subway") OR ("Metro stations") OR ("Metro station") OR ("Subway mall") OR ("Underpass") OR ("Subway lines") OR ("Metropolitan") OR ("Metropolitan area") OR ("Underground area") OR ("Rail transit") AND ("environmental factors") OR ("environmental requirements") OR ("environments requirements") OR ("environmental factor") OR ("environmental") AND 1990/01/01[PDAT] : 2019/01/20[PDAT] | 645 |
| 2         | ((Evacuation[tiab]) OR ("emergency evacuation" [tiab]) OR ("Pedestrian evacuation" [tiab]) OR ("Passenger flow") OR ("Passenger evacuation" [tiab]) OR ("Evacuation capability") OR ("Evacuation capacity") OR ("Evacuation plan") OR ("Evacuation strategy") OR ("Evacuation strategies") OR ("Evacuation route") OR ("Evacuation safety") OR ("Evacuation efficiency") OR ("Crowd evacuation") OR ("Evacuation performance") OR ("Evacuation times") OR ("Evacuation behaviors") OR ("Evacuation parameters") OR ("Evacuation features") OR ("Evacuation analysis") OR ("Evacuation facilities") OR ("Evacuation possibilities") OR ("Possible evacuation") OR ("Evacuation situation") OR ("Evacuation techniques") OR ("Evacuation scenario") OR ("Staged evacuation") OR ("Evacuation models") OR ("Evacuation performance") OR ("evacuation time") OR ("evacuation process") OR ("safe evacuation") OR ("passenger evacuation") OR ("human evacuation") OR ("humans evacuation") OR ("personnel evacuation") OR ("passengers evacuation") OR ("evacuation centers") OR ("evacuation center") OR ("safety evacuation") OR ("Fire evacuation") OR ("evacuation design") OR ("Safely evacuation") AND (("subway stations") OR ("rail roads") OR ("subway station") OR ("subway fire") OR ("Metro") OR ("Urban rail") OR ("Urban transit") OR ("Urban station") OR ("Subway") OR ("Subway accidents") OR ("subway incidents") OR ("subway events") OR ("Underground station") OR ("Subway fire") OR ("Railway stations") OR ("Underground stations") OR ("Crowded subway") OR ("Metro stations") OR ("Metro station") OR ("Subway mall") OR ("Underpass") OR ("Subway lines") OR ("Metropolitan") OR ("Metropolitan area") OR ("Underground area") OR ("Rail transit") AND ("environmental factors") OR ("environmental requirements") OR ("environments requirements") OR ("environmental factor") OR ("environmental") AND 1990/01/01[PDAT] : 2019/01/20[PDAT] | 126 |
### 4. Search syntax in ProQuest for environmental factors affecting the safe emergency evacuation in subways

| Syntax number | Syntax | Description | Records number |
|---------------|--------|-------------|----------------|
| 1             | (ALL (Evacuation) OR ALL("emergency evacuation") OR ALL("Pedestrian evacuation") OR ALL("Passenger flow") OR ALL("Passenger evacuation") OR ALL("Evacuation capability") OR ALL("Evacuation capacity") OR ALL("Evacuation plan") OR ALL("Evacuation strategy") OR ALL("Evacuation strategies") OR ALL("Evacuation route") OR ALL("Evacuation safety") OR ALL("Evacuation efficiency") OR ALL("Crowd evacuation") OR ALL("Evacuation performance") OR ALL("Evacuation times") OR ALL("Evacuation behavior") OR ALL("Evacuation parameter") OR ALL("Evacuation features") OR ALL("Evacuation analysis") OR ALL("Evacuation facilities") OR ALL("Evacuation possibilities") OR ALL("Possible evacuation") OR ALL("Evacuation situation") OR ALL("Evacuation techniques") OR ALL("Evacuation scenario") OR ALL("Evacuation”) OR ALL("Evacuation performance") OR ALL("evacuation time") OR ALL("evacuation process") OR ALL("safe evacuation") OR ALL("passenger evacuation") OR ALL("human evacuation") OR ALL("humans evacuation") OR ALL("personnel evacuation") OR ALL("passengers evacuation") OR ALL("evacuation centers") OR ALL("evacuation center") OR ALL("safety evacuation") OR ALL("Fire evacuation") OR ALL("evacuation design") OR ALL("Safely evacuation") AND ALL("subway stations") OR ALL("rail roads") OR ALL("subway station") OR ALL("subway fire") OR ALL(Metro) OR ALL("Urban rail") OR ALL("Urban transit") OR ALL("Urban station") OR ALL(Subway) OR ALL("Subway accidents") OR ALL("Underground station") OR ALL("Subway fire") OR ALL("Railway stations") OR ALL("Underground stations") OR ALL("Crowded subway") OR ALL("Metro stations") OR ALL("Metro station") OR ALL(Subway- mall) OR ALL(Underpass) OR ALL("Subway lines") OR ALL(Metropolitan) OR ALL("Metropolitan area") OR ALL("Underground area") OR ALL("Rail transit") AND ALL("environmental factors") OR ALL("environmental requirements") OR ALL("environments requirements") OR ALL("environmental factor") OR ALL(environmental) AND YR (19900101-20190120) | Scholarly journals: 11 | Dissertation and theses: 28 | 39 | Feature

### Appendix 2: Data extraction form of systematic review on environmental and organizational management-related factors affecting the safe emergency evacuation from subway stations

**A: Identification information**

1. Study code
2. Study title
3. First author
4. Publication year
5. Country
6. Study design

**B: Specific goals of systematic review**

Factors affecting passenger’s safe evacuation from subways, in normal conditions

Environmental factors affecting safe emergency evacuation from subway, in emergency conditions

Organizational and managerial factors affecting safe emergency evacuation from subway, in emergency conditions

Subways risk factors of emergency evacuation

Evacuees vulnerability in emergency evacuation
**Appendix 3:** Critical appraisal checklist of articles in systematic review of environmental and organizational management-related factors affecting the safe emergency evacuation from subway stations

| Reviewer | Manuscript Code | Author | Review date | Journal | Publication date |
|-----------|----------------|--------|-------------|---------|-----------------|

| 1. Screening question | Yes | NC | No | NA |
|----------------------|-----|----|----|----|
| 1.1. Is study about subway emergency evacuation? |  |
| 1.2. Does study include safe evacuation parameters? |  |

| 2. Study design/type of study | Yes | NC | No | NA |
|-------------------------------|-----|----|----|----|
| 2.1. Is it quantitative study design? |  |
| Simulation |  |
| Cross-sectional |  |
| Case–control |  |
| Case report |  |
| Cohort |  |
| Experimental |  |
| Quasi-experimental |  |
| Content analysis |  |
| Phenomenology |  |
| Grounded theory |  |
| Ethnology |  |
| 2.2. Is it qualitative study design? |  |
| 2.3. Is it mix method of quantitative and qualitative study? |  |

| 3. Findings | Yes | NC | No | NA |
|-------------|-----|----|----|----|
| 3.1. Findings are presented in clear, intelligible manner with sufficient detail for decision-making |  |
| Well-presented aspects of a concept (emergency evacuation) |  |
| Well-presented aspects of a concept (safety in evacuation) |  |
| 3.2. Are findings described well? |  |
| 3.3. Are findings based on study question? |  |

| 4. Strength of recommendations | Yes | NC | No | NA |
|-------------------------------|-----|----|----|----|
| 4.1. Is study consistent with evidence? |  |
| Based on empirical evidence |  |
| Studies done within the underground, metro, subway stations |  |
| Study presented a model |  |
| Study presented hypotheses |  |
| Well description of findings |  |

NC: Not clear, NA: Not applicable