The Standard Operational Procedure (SOP) development of fire-safety system in Jakarta Mass Rapid Transit (MRT) based on risk analysis

G N Retriana*
Civil Engineering Department, Faculty of Engineering, University of Indonesia
Salemba, Jakarta, Indonesia

*gresilia79@gmail.com

Abstract. Mass Rapid Transit (MRT) is one of the most useful transportations in Jakarta. The passengers of MRT gradually increase when compared to previous users. However, MRT has a potential fire and it definitely will create the number of victims. Prevention efforts such as Standard Operational Procedure (SOP) of appropriate fire safety system. This study aims to know a gap between regional regulations related to fire safety system with the existing Jakarta MRT fire safety SOP, to identify the dominant risk factors in the Jakarta MRT fire safety SOP and to develop a fire safety system SOP on the MRT in Jakarta. The method used in this study is based on research strategies consisting of archive analysis, literature study, survey and case study. The result showed that there was a gap between MRT Jakarta Standard Operational Procedures and Building Fire Safety Regulations for Buildings in Indonesia. The SOP development of fire-safety system in Jakarta Mass Rapid Transit (MRT) is no specific SOP that defines the description of activities within meet fire safety SOPs. In conclusion, the making of the procedures in this study update the old procedures and make new procedures for processes, which do not have procedure yet.

1. Introduction
High and crowded population is one of the serious matters in Jakarta, Indonesia. It also causes a traffic jam on the long road. This condition disturbs the activities of citizen and decreases the productivities. Through restricted access and traffic congestion, most municipalities suffer from delicate form of transport problems. Transport issues increase and become more complex as the city is building up in size. The congestion becomes greater when the city center is building up the skyscraper blocks whose offices sometimes employ thousands of workers. Everyone leaves the building at the end of office hours and goes home directly. It creates substantial pressure on public transports and take much longer times of journey than in normal hours. It also will affect to social and economic development of the country. Environmental pollution increases because of the traffic delay and overcrowding. The vehicles perhaps are parked along the roadside restricting movement to a narrow lane and causing narrow streets, sharp comers. The traffic jam may slow down the movement and creates greater congestion. An imbalance of psychological behavior of the road users may lead to the next risks further such as accident [1]. It needs an effective mass transportation that can handle this matter and make better condition of Jakarta’s transportation system.
Mass Rapid Transit (MRT) is one of the best choices in overcoming the issue of the metropolitan city. It is an effort to solve one of many transportation problems. MRT gives a merit for increasing the time efficiency since it has large capacity, low energy consumption, high speed and high technology. Currently, a lot of citizen in Jakarta tends to use the MRT as their choice [2,3]. With the new mass transportation in Jakarta, MRT is expected to become a role model of effective transportation for other capital cities and can provide a new choice to those who used private vehicles before to use MRT. The MRT is expected to reduce the level of congestion in capital city. People who live in the capital city will feel so much helpful because this new transportation travel time will take shorter than riding a private vehicle [4].

Table 1. Passenger train fires in the last 10 years.

| No. | Nation                     | Years                  | Cause of Fire                                                                 | Victims                          | Source                                                                                           |
|-----|----------------------------|------------------------|-------------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------------------------------------------|
| 1   | United States of America   | November, 22nd 2019    | A Metrolink train collided with a trailer that stopped at the railroad in Santa Fe Springs | 4 people were injured            | List of rail accidents (2010–2019), Wikipedia, 2019                                              |
| 2   | Mexico                     | May, 20th 2018         | Two Ferromex trains collided between the cities of Chihuahua and Ciudad Juarez, fire exploded from the train. The accident was caused by human error, the train went beyond the official speed limit and went off the road | The engineer was killed and 5 other train members were injured | “One dead in Chihuahua train crash; human error blamed”. *Mexico News Daily*, 31 May 2018. Retrieved 2 June 2018 |
| 3   | United States of America   | June, 27th 2017        | A New York City subway headed south then slipped on fire near 125th Street. The train slipped due to improper replacement rails | 39 people were slightly injured  | “MTA: Unsecure Rail Stored on Tracks Caused Harlem Subway Derailment”. NY1. 28 June 2017. Archived from the original on 28 June 2017. Retrieved 29 June 2017 |
| 4   | Iran                       | November, 25th 2015    | The Semnan-Damghan train collision. Four trains slipped (two of them on fire) after a passenger train crashed into a second train passenger that broke down in Haf-Khan, Semnan Province | 49 people were killed and 103 injured | List of rail accidents (2010–2019), Wikipedia, 2019                                              |
| 5   | United States of America   | August, 17th 2014      | Two Union Pacific locomotives collided in Hoxie, Arkansas. Several carriages slipped, resulting in a fire that caused ‘evacuation of 500 residents’ | 2 crew members died and wounded 2 others | “Update: Hoxie Train Wreck Victims Identified, Investigation Continues”. *Arkansas Matters/Nexstar Broadcasting*, 18 August 2014. Retrieved 3 October 2014 |
| 6   | India                      | December, 28th 2013    | The Hazur Sahib Nanded express caught fire near Kothacheruvu in the Anantapur district in Andhra Pradesh | 26 people were killed and 12 people were injured | List of rail accidents (2010–2019), Wikipedia, 2019                                              |
| 7   | India                      | July, 30th 2012        | The Nellore train fire occurred at dawn. Nellore Railway in Delhi-Chennai Tamil Nadu Express. The incident in Nellore, Andhra Pradesh | 32 passengers were killed and 27 injured | “India train fire kills 47 in Andhra Pradesh”. *BBC News*, 30 July 2012.                          |
| 8   | United States of America   | June, 22nd 2011        | Two Union Pacific trains crashed into each other east of Goodwell, about 480 kilometers northwest of Oklahoma City | 3 people died                    | “U.S. News | National News-Latest Headlines, Videos, Photos-ABC News". *Abcnews.go.com*, 20 May 2013. Retrieved 31 May 2013 |
| 9   | United Kingdom             | June, 7th 2010         | A ScotRail passenger train collided with large rocks that fell in a line near Cruachan Falls, slipping and burning. | Some people were hospitalized and the tunnel was blocked for a week | “Boulders caused rail derailment”. *BBC News*, 7 June 2010                                           |
Currently, the volume of MRT Jakarta passengers increases gradually, it means the safety, security and service must be improved in operational work. The number of MRT Jakarta passengers reaches 79,114 per day on average. In December 18, 2019, the passengers reached 94,785 people per day [5]. Compared to other train transportation, the density of passengers per unit of the MRT area is getting higher but the available space for people to move is still relatively low. If something unexpected happens, it will cause more panic attack and confusion for passengers if compared to similar situations that occur on buses and other land transportations. As a result, it is very difficult to evacuate people from dangerous spot to the safe places, especially in the existing underground transportation system like the MRT. During the fire emergency, the safety of a passenger is highly impending above the evacuation process. That is why a Standard Operating Procedure (SOP) is required. When analyzing safety in a train tunnel, there is an uncertainty regarding the characteristics of fires. Therefore, it needs a problem approach in the term of technical approaches, especially the determination of fire size, endurance assessment, smoke control system design, evaluation of passenger evacuation time. Even though the advance science and technology have been applied to buildings and industries, it cannot be separated from various risks including fires, floods, earthquakes, hurricanes, and other [6].

The biggest accidents that occurred in the underground transportation system were the fire at King’s Cross-station in 1987, the Metro Baku fire in 1995, the fire in the Kaprun railroad tunnel in 2000 and the Daegu subway fire in 2003. One of the cases of Metro Baku fire incidents, which occurred on October 28, 1995, found around 220 passengers died on the train and other 80 passengers died of smoke inhaled while walking along the tracks to the nearest station. In the Baku incident, lack of communication and operation of the ventilation system caused death, about 15 minutes after the fire started, an emergency ventilation system was activated which directed the smoke towards the majority of passengers. This is possible due to lack of communication from the control room due to ignorance of what actually happened at the source of the fire [7]. Fires in road and rail tunnels are very dangerous because burning can be deadly to humans and can spread several kilometers along the tunnel [8].

At underground stations and MRT lines, a special approach is needed and investment costs are more expensive with high limitations. The smooth operation of all these complexities is ensured by a comprehensive MRT operational system design, it has been compared to other big cities MRT systems, such as in Singapore and Japan. The development of building structures should consider fire safety system. There are four things are needed to consider regarding fire hazards, there are occupants of buildings (humans), contents of buildings (assets), building structures, and buildings are located close each other [9]. So, the role of SOPs in the MRT signaling system becomes crucial since many accidents of MRT system in several countries happen [10].

The study about Jakarta MRT fire safety system SOPs is still limited. However, the lack of research information about the fire safety system SOP of Jakarta MRT will be the basis of this research. Therefore, this study aims to develop the fire safety system SOP of Jakarta MRT based on risk analysis. This study will give benefits to the Jakarta railway MRT Corporation as a reference in improving the current SOPs. Moreover, this study will help decreasing the victims if there are accidents in the future.

2. Methodology

Method used in this research follows the method Yin [10]. The method is based on research strategy consists of archive analysis, survey, literature study and case study. The explanation regarding the research strategy used in this study are:

2.1. Archive analysis

In this study, the archive analysis is used to obtain supporting material in the form of references related to this research. The source of the archive analysis consists of regulations, decisions, instructions issued by the government.
2.2. Literature study

Literature study is a method by collecting data derived from literature and documents related to research. This method is used to identify fire safety conditions and how to prepare appropriate procedures. In this study, a literature study is used to obtain supporting material in the form of references related to this research. The sources of the study of literature consist of journals, theses, and official institutions.

2.3. Survey

In this study, the survey method is divided into 2 (two) parts, namely questionnaire and interview. Where the questionnaire was carried out using a specially designed questionnaire in the hope that respondents answered all questions easily, and precisely so that the results obtained were in accordance with the results of the study. In addition, interviews are conducted with personnel who have authority in decision making in the company or agency they lead with the aim of validating the answers to the questionnaire or it can also be done answering the questionnaire directly with special interviews.

2.4. Case study

One of the specificities of case study research as a research method is its purpose. Case study research is very appropriate to be used in research that aims to answer the question 'how' and 'why' of the research. Through such research questions, the basic substances contained of the cases under the study can be explored in depth. In other words, case study research is appropriate for explanatory research that is research intended to explore explanations of causality, or the causes and consequences contained of the object this research. A case study is carried out on the risk-based fire safety system, in order to reduce fatalities. The appropriate preventive and corrective actions can be taken on the causes and impacts of fire risks.

3. Results and discussion

In recent years, many fatal fire accidents have occurred in all tunnels and underground in the world (in Table 1.). After the fire accident, there were serious discussions at the local and international level about how to manage fires in tunnels for transportation and underground stations. However, it is difficult to reach the final conclusion regarding international standards, because the conditions and requirements of each country are different. In some countries, regulations or standards for fire management or management are very strict but some are not in other countries. According to tunnel types and underground structures (road tunnels, railroad or metro tunnels and underground stations), the characteristics of the cause of fire accidents, fire load / size and emergency response methods are also different. However, the difference in characteristics is sometimes not easy to be studied. Management and countermeasures are planned and implemented without consideration.

3.1. Building fire safety regulations for buildings in Indonesia

3.1.1. Law of the Republic of Indonesia. The Law of the Republic of Indonesia, which regulates building fire safety, is the Law of the Republic of Indonesia Number 28 of 2002 concerning building construction. In this act, a building is a physical form of construction work that is united with its domicile, partly or wholly on top and / or in land and / or water, which has functions as a place for humans to carry out their activities, both for occupancy or residence, religious activities, business activities, social activities, culture, and special activities.

Each building must meet administrative and technical requirements in accordance with the function of the building. Administrative requirements of buildings include the requirements for the status of land rights, ownership status of buildings, and building permits. The building technical requirements include building layout requirements and building reliability requirements. The building reliability requirements referred to include the requirements for safety, health, comfort, and convenience (Law of the Republic of Indonesia Number 28 of 2002).
Building safety requirements include building capabilities to support load loads, as well as the ability of buildings to prevent and combat fires. Requirements of the ability of buildings to prevent and cope with fires are the ability of buildings to carry out security against fire hazards through passive protection systems and / or active protection. Security against fire hazards is carried out with a passive protection system that includes the stability of the structure and its elements, fireproof construction, compartmentalization and separation, and protection of existing openings to hold and limit the speed at which fire and smoke spread.

Security against fire hazards is carried out with an active protection system including the ability of equipment to detect and extinguish fires, smoke control, and fire rescue facilities. Buildings, other than residences, must be equipped with passive and active protection systems (Law of the Republic of Indonesia Number 28 of 2002).

3.1.2. Government Regulation of the Republic of Indonesia. Based on Law No. 28 of 2002, the Government of the Republic of Indonesia has issued Government Regulation of the Republic of Indonesia No. 36 of 2005 concerning Regulations for Implementing Law Number 28 of 2002 concerning building construction. This regulation states that the reliability requirements of a building include safety, health, and convenience requirements. The safety requirements referred to in this regulation include the ability of buildings to support loads, as well as the ability of buildings to prevent and overcome fire hazards.

Every building, except a single dwelling house and simple series house, must be protected against fire hazards with an active protection system and passive protection. The application of a passive protection system is based on the function or classification of fire risk, spatial geometry, installed building materials, and / or the number and condition of occupants in the buildings. While the application of an active protection system is based on the function of classification, area, height, volume of buildings, and / or the number and condition of occupants in buildings. The active protection system in question is based on providing equipment that can work both automatically and manually, used by residents or fire-fighters in carrying out blackout operation. Provisions of fire safety equipment as an active protection system includes the provision of detection and alarm system, fire hydrants are outside and inside buildings, lightweight fire extinguishers, and sprinklers. In addition to the protection system, every building with a function, classification, area, number of floors, and or with a certain number of occupants must have a fire safety management unit. The provisions regarding the procedures for planning, installing, maintaining active and passive protection system as well as implementing fire safety management must follow the applicable guidelines and standards (PP No. 36 of 2005).

In this regulation also explained that every building with height above 5 (five) floors must provide means of vertical connection in the form of a lift. Every building that uses a lift must provide fire lifts. Fire lifts can be in the form of special fire lifts or ordinary passenger lifts or goods lifts which can be arranged for operation. So, in emergency situation they can be specifically used by fire officials (PP No. 36 of 2005).

3.1.3. Ministerial regulations. The Ministry of Public Works issued Minister of Public Works Regulation Number 26 / PRT / M / 2008 Regarding Technical Requirements for Fire Protection System of Buildings and Environment. This Ministerial Regulation is intended to be a reference for building operators in order to realize construction which is safe from fire hazards.

This regulation aims to carry out the functions of building and environment which is safe for humans, property, especially from the danger of fire, so, it will not make such a disruption of social welfare. The scope of this ministerial regulation covers the fire protection system of the buildings and environment starting from the planning stage, the implementation of development to the utilization stage, so that the building is always reliable and of quality in accordance with its function.

3.1.4. Ministerial decree. In addition to the government regulations mentioned above, the government of the Republic of Indonesia, in this case, the department or ministry of public works also issued a
The ministerial decree of the technical provisions on procedures for planning, installing; maintaining active and passive protection system; and implementing fire safety management. These decisions are:

- **Decree of the State Minister of Public Works No. 10 / KPTS / 2000 Concerning Technical Provisions for Safeguarding Fire Hazards in Buildings and Environments.** The security measures for fire hazards in the building and environment referred to implementation of building security from the accidents such as fire hazards. It started from the planning, implementation of development to the utilization stage. So, the building is always reliable and good on quality regarding with its function. While the purpose of the security measures against fire hazards in buildings and the environment is to carry out the functions of buildings and environments that are safe for humans, property, especially from fire hazards. So, it will not make such a disruption in goods and services production or distribution, even though the problem comes from social welfare disturbances.

- **Decree of the State Minister of Public Works No. 11 / KPTS / 2000 concerning Technical Provisions on Fire Management in Cities.** The fire management in urban areas is intended to create buildings, environments and municipalities which are safe from fire hazards through the implementation of effective and efficient fire hazard management. The fire management in urban areas aims to realize the preparation, awareness, and community empowerment, building managers, and related agencies in preventing and overcoming fire hazards.

### 3.1.5. Regional regulation

The autonomy system that is applied to the entire territory of Indonesia makes each local government must have their respective regional regulations that still refer to the regulations of the central government. Local regulations that contain fire prevention and control are as follow:

- **DKI Jakarta Provincial Regulation No. 8 of 2008 concerning Fire Prevention and Management.** The scope of this Jakarta Regional Regulation covers objects and potential fire hazards, fire prevention systems such as life-saving facilities, fire extinguisher access, fire protection, and building fire safety management, fire prevention, system testing, fire safety control and others

- **PT. Jakarta MRT in fire disaster prevention and management also has several regulations or Standard Operating Procedures (SOP).** The SOPs are:
  
  - Instructions for Train Operation during Disturbance and Emergency (V2.03c) can be found in Section 8, namely Operation in the event of a fire. Section 8 is divided into 2 chapters namely CHAPTER 1 Fire on a train consisting of 4 articles, and CHAPTER 2 Fire at the station consists of 3 articles.
  
  - Directors' Regulations PT. Jakarta MRT (Perseroda) Number 019 of 2019 concerning Guidelines for Passenger Announcement and Evacuation in Station (MRT) 21 in the Passenger Announcement (PA) 21 and PAE Evacuation Manual E1-1 and E1-2
  
  - Manual for Safety is contained in article 4 Emergency Operations, namely 4.1 Emergency cases, 4.2 Total management procedures for Fire
  
  - Directors' Regulations PT. Jakarta MRT Number 034 of 2018 concerning Occupational Safety and Health Management System, Railway Safety Management System and Security Management System in the PT. Jakarta MRT can be found in section 6 Procedure Description namely 6.1 Handling Emergency Conditions - Fire, 6.11 Evacuation, 6.12 Evacuation of Employees / Guests with Physical Limitations, 6.13 Emergency Response simulations, 6.17 Emergency Response Team Structure extinguisher access

### 3.2. GAP analysis results

The results of the GAP analysis in the form of proposals obtained from the analysis of the present conditions with an analysis of standard ideal conditions is used as a reference. The following Table 2 is a summary of the results of the GAP analysis.
Table 2. GAP analysis results.

| Process                                                                 | Weakness                                                                 | Recommendation                                                                 |
|------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Instructions for Train Operation during Disturbance and Emergency      | The current SOP is just a chart, it does not include an explanation of every process in chart. | The remaking of SOPs is based on guidance from existing regulations in Indonesia |
| (V2.03c) can be found in Section 8, namely                             |                                                                          |                                                                              |
| Operation in the event of a fire. Section 8 is divided into             |                                                                          |                                                                              |
| 2 chapters namely CHAPTER 1 Fire on a train consisting of 4 articles,   |                                                                          |                                                                              |
| and CHAPTER 2 Fire at the station consists of 3 articles.              |                                                                          |                                                                              |
| Instructions for Train Operation during Disturbance and Emergency (V2.03c) can be found in Section 8, namely Operation in the event of a fire. Section 8 is divided into 2 chapters namely CHAPTER 1 Fire on a train consisting of 4 articles, and CHAPTER 2 Fire at the station consists of 3 articles. |                                                                          |                                                                              |
| The current SOP is just a chart, it does not include an explanation of every process in chart. |                                                                          |                                                                              |
| The remaking of SOPs is based on guidance from existing regulations in Indonesia |                                                                          |                                                                              |
| Defining status is still not good because there is a status that indicates more than one condition. |                                                                          | Redefinition of risk status based on fire safety guidelines                    |
| There are no priority defining activities based on impact and urgency of the incident. |                                                                          | Redefinition of priority level based on impact and urgency.                    |
| SOPs are still separated, not in 1 integrated SOP |                                                                          | Add the knowledge base activity into the SOP and create suggestion about knowledge base design. |
| Directors' Regulations PT. Jakarta MRT (Perseroda) Number 019 of 2019 concerning Guidelines for Passenger Announcement and Evacuation In Station (MRT) 21 in the Passenger Announcement (PA) 21 and PAE Evacuation Manual E1-1 and E1-2 | There is no specific SOP that defines the description of activities within meet fire safety SOPs | Making a SOP as a whole and integrated system                                   |
| Manual for Safety is contained in article 4 Emergency Operations, namely | There is no specific SOP that defines the description of activities related to emergencies. | Making a SOP as a whole and integrated system based on existing regulations in the DKI Jakarta provincial government |
| 4.1 Emergency cases, 4.2 Total management procedures for Fire           |                                                                          |                                                                              |
| Directors' Regulations PT. Jakarta MRT Number 034 of 2018 concerning Occupational Safety and Health Management System, Railway Safety Management System and Security Management System in the PT. Jakarta MRT can be found in section 6 Procedure Description namely 6.1 Handling Emergency Conditions - Fire, 6.11 Evacuation, 6.12 Evacuation of Employees / Guests with Physical Limitations, 6.13 Emergency Response simulations, 6.17 Emergency Response Team Structure extinguisher access | Each SOP is separate and has not been adjusted to the existing regulations in Indonesia, especially the regulations issued by the DKI Jakarta Provincial Government | Making a SOP as a whole and integrated system based on existing regulations in the DKI Jakarta provincial government |

3.3. SOP document development

This chapter is the stage of designing the SOP document which will be based on the result of proposals from the gap analysis. Procedures are designed based on existing processes that are adapted to the processes in SOP of fire safety needs. The making of the procedures in this study update the old procedures and also make new procedures for processes which do not have procedure yet.

4. Conclusion

Fire safety regulation which issues for Jakarta MRT and its application can have divided into three categories namely performance institutions, regulatory substance and mechanisms application of regulations. On the substance of regulation, a common problem is regulations quality whereas specifically, there are problems with component aspects of the system required fire protection. Component which is related to extinguishing access fire, protection system, evacuation facilities. Fire Command Center laying requirements (FCC), related to the evacuation component on the MRT. At the application stage mechanism, problem consists of process workmanship or implementation in the
preparation regulations, regulatory positions, licensing processes, improved regulations, and applied approaches performance-based.

This study is a preliminary study with a sample limited to reach completion of this problem, with discussion with the forum is bigger and more participants are expected to reach recommendations that lead to improved regulations and their applications.

References
[1] Babu A M 2017 Study of Urban Cities Traffic Problems Due to Delay and Overcrowding International Journal of Latest Engineering and Management Research 11 01-08
[2] Jakarta Smart City 2018 Uji Coba MRT dengan Sistem Persinyalan Canggih [Online] Retrieved from https://smartcity.jakarta.go.id Accessed on April 7, 2020
[3] Jakarta MRT 2017 Tiga Upaya MRT Tekan Emisi [Online] Retrieved from https://www.jakartamrt.co.id. Diakses pada 7 April 2020 Accessed on April 7, 2020
[4] Simorangkir E 2018 MRT Jakarta, Transportasi Masa Depan Pemecah Macet Ibu Kota [Online] Retrieved from https://finance.detik.com Accessed on April 7, 2020
[5] Jakarta MRT 2019 Penumpang MRT Jakarta Terus Meningkat [Online] Retrieved from https://www.jakartamrt.co.id Accessed on April 1, 2020
[6] Wahyudono U 2016 Masyarakat Profesi Proteksi Kebakaran Indonesia (MP2KI)
[7] RailSystem 2015 Baku Metro Fire (1995) Retrieved from http://www.railsystem.net Accessed on April 1, 2020
[8] Haddad R K, Reda E, Rasani M R, Zedan C K and Harun Z 2018 Fire Simulation of a Scaled Mass Rapid Transit (MRT) Tunnel Journal of Mechanical Engineering 1 1-17
[9] Hesna Y, Hidayat B and Suwanda S 2009 Evaluasi penerapan sistem keselamatan kebakaran pada bangunan gedung rumah sakit dr. M. Djamil padang Jurnal Rekayasa Sipil (JRS-Unand) 5 2 65-76
[10] Setyoko A T and Purwanto E H 2020 Parameter Teknis Dalam Usulan Standar Persinyalan Pada Sistem Transportasi Mass Rapid Transit (MRT) Jurnal Standardisasi 22 1 73-84