THE EFFECTIVENESS OF FIRE PROTECTION SYSTEM FOR BUKIT BERAPIT HIGH-SPEED RAIL TUNNEL

ABDUL KHAIR BIN OSMAN

OPEN UNIVERSITY MALAYSIA
2021

THE EFFECTIVENESS OF FIRE PROTECTION SYSTEM FOR BUKIT BERAPIT HIGH-SPEED RAIL TUNNEL

ABDUL KHAIR BIN OSMAN

A Master's Project submitted in fulfilment of the requirements for the degree of Master of Occupational Safety and Health Risk Management

Open University Malaysia
2021

DECLARATION

Name: Abdul Khair Bin Osman

Matrix Number: CGS01058130

I hereby declare that this Master's Project is the result of my own work, except for quotations and summaries which have been duly acknowledged.

Signature:  Date: 10/03/2021

THE EFFECTIVENESS OF FIRE PROTECTION SYSTEM FOR BUKIT BERAPIT HIGH-SPEED RAIL TUNNEL

ABSTRACT

The development of technology in transportation industry especially rail transportation is an alternative solution to Malaysia Transportation Issues. The initiative of the government to develop Mega Project such as Electrics Train Service (ETS) in the year 2015, consisting the railway from Kuala Lumpur to Padang Besar, Perlis and it helps to reduce the amount of traffic on road and lessen the time spent to travel from these two places. This project includes the building up of two unique Train Tunnels and categories as Twin Tunnel that are 3.3kilometre length in Bukit Berapit and 1.1kilometre length in Bukit Larut, Perak. The Twin Railway Tunnel in Bukit Berapit, Perak is the longest in Malaysia ever built. The development of this twin train tracks is brought by the local engineering expertise with the advisory by international expert. One of the important components of its development is to ensure the main build up standards and life safety in this twin railway tunnel project is given priority. Based on the statistics by Bureau of Transportation in United States, accident that involved in Train Tunnels are 11 accidents and resulting 343 death and 81 injuries with multiples factor most of it caused by electrical failure and results to fires. Based on the statistics, 2 most important safety element in developing Bukit Berapit Twin Railway Tunnel are life safety and properties of the building. The safety elements need to be considered are fire protection system and the fire retardant material. The preliminary concept of this project is using the combination of Italian Standards and NFPA 130, since there are no local standards to be referred. This research focused on the best standard practises from other countries for the purpose to evaluate the effectiveness of fire protection system used in Bukit Berapit Railway Tunnel. Therefore, a few researches on standard's, site visits, survey and interviews the expert had been conducted. Based on the research findings, there are 10 parameters identified and it will be suggested as a benchmark on making standards in building up Railway Tunnel in Malaysia in the future. Fires is a great danger to human life especially when occurs in a confined space. Railway tunnel fires is uncommonly occurred, and railway tunnels typically require large investments in providing fire protection. It is necessity to understand the reasons for the first consideration in developing railway tunnel in such of fire safety. As this railway tunnel is the first project in Malaysia and has no local standard, much attention needs to be given to fire prevention, such as stability, integrity, and structural assessment during fire and fire extinguishing system reactions. Two factors will be focused mainly on: passive fire protection system and active fire extinguishing system to study the effectiveness of fire safety concept for Bukit Berapit tunnel.

Keywords: Railway tunnel, fire safety system, local standard

KEBERKESANAN SISTEM PERLINDUNGAN KEBAKARAN UNTUK BUNIT BERAPIT TUNNEL RAIL BERKELAJUAN TINGGI

ABSTRAK

Perkembangan teknologi didalam industri pengangkutan rel merupakan alternatif terbaik kepada industri pengangkutan di Malaysia. Dengan terlaksananya projek Electric Train Service (ETS) yang melibatkan jajaran dari Kuala Lumpur ke Padang Besar Perlis pada tahun 2015 dapat menjimatkan masa dan mengurangkan kesesakan jalan raya. Projek ini melibatkan pembinaa dua terowong iaitu terowong berkembar sepanjang 3.3 km di Bukit Berapit, Perak dan terowong di Bukit Larut, Perak sepanjang 1.1km. Terowong Berkembar Bukit Berapit adalah terowong keretapi terpanjang dan pertama di Malaysia. Pembinaan terowong ini dilaksanakan oleh jurutera tempatan dengan dibantu pakar luar negara. Salah satu keperluan pembinaan terowong berkembar ini adalah penentuan keperluan keselamatan kebakaran. Mengikut statistik yang dikeluarkan oleh *Bureau of Transpotation Statistic* dari Amerika Syarikat, kemalangan keretapi didalam terowong adalah berjumlah 11 kes melibatkan kematian sebanyak 343 dan 81 kecederaan yang disebabkan oleh faktor kebakaran yang berpunca daripada kegagalan system elektrik. Justeru itu, dua elemen penting didalam pembinaan terowong berkembar Bukit Berapit perlu diberi perhatian serius adalah pepasangan keselamatan kebakaran aktif dan pasif selain stukturnya mestilah menggunakan bahan tidah mudah terbakar dan stabil semasa kebakaran. Di dalam menentukan keperluan keselamatan kebakaran terowong keretapi Bukit Berapit, gabungan standard dari negara Itali dan NFPA 130 menjadi asas rujukan disebabkan tiadanya standard tempatan sebagai rujukan. Kajian ini adalah untuk mengenalpasti adakah sistem-sistem perlindungan kebakaran yang terdapat di dalam terowong Bukit Berapit memenuhi parameter piawaian antarabangsa. Untuk tujuan itu, beberapa kajian, tinjauan dan temuramah dengan pakar-pakar yang diiktiraf telah dilaksanakan bagi mengetahui piawaian apakah yang terbaik untuk digunakan dalam menguruskan keselamatan kebakaran di terowong keretapi. Hasil kajian yang diperolehi semasa soal selidik, temuramah dan pemerhatian mendapati, sepuluh parameter digunakan dan diterapkan dalam aspek keselamatan kebakaran di terowong keretapi. Hasil kajian ini juga boleh dijadikan input bagi pembangunan standard tempatan pada masa akan datang.

Kata Kunci: Terowong keretapi, Pepasangan Keselamatan Kebakaran, standard tempatan,

ACKNOWLEDGEMENTS

I would like to take this oppurtinity to express my gratitude and appreciation to my supervisor, Ir Faizal Bin Musa guidance, patience and invaluable advise throughout this project.

I also would like to express my appreciation to my family and friends for theis endless support whenever I face problem. Without the mentioned parties, it is imposisible for me to complete this project report successfully.

THANK YOU.

ABDUL KHAIR BIN OSMAN

10 March 2021

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST ABBREVIATIONS

CBA	Cost-Benefit Analysis
CCTV	Closed-Circuit Television
CFD	Computational Fluid Dynamics
DOE	Department Of Environment
DOSH	Department of Occupational Safety and Health
ECRL	MRL East Coast Rail
EPF	Employees Provident Fund
ERL	Express Rail Link
ERP	Enterprise Resource Planning
FFFS	Fixed Fire Fighting Systems
FIT	Fire In Tunnels
FM	Frequency
FPGA	Field Programmable Gate Array
FRDM	Fire and Rescue Department
FTA	Federal Transit Administration
HAZMAT	Hazardous Material
HGV	Heavy Goods Vehicle
HIRARC -	Hazard Identification , Risk Assessment and Risk Control
IMs	Intra Management System
JBPM	Jabatan Bomba dan Penyelamat Malaysia
JKR	Jabatan Kerja Raya
JPBD	Jabatan Perancangan Bandar Dan Desa
KTMB	Keretapi Tanah Melayu Berhad
LHD	Linear Heat Detection

LNG	Liquefied Natural Gas
LTA	Land Transport Authority
MITI	Ministry of International Trade & Industry
MOH	Ministry of Health
MS	Malaysian Standard
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NTSB	National Transportation Safety Board
OCC	Operation Control Centre
OHSAS	Occupational Health and Safety Assessment Series
OSHA	Occupational Safety and Health Administration
PDRM	Polis Diraja Malaysia
RSET	Reliable Evaluation Safety Time
SAFE	Simple Agreement For Future Equity
SOLIT	Safety of Life in Tunnels
TNB	Tenaga Nasional Berhad
TSI	Technical Specifications for Interoperability
UBBL	Uniform Building By-Laws
UIC	University of Illinois at Chicago
UPTUN	Upon Tunnels

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

The 3300 m Twin Tunnel is Malaysia's longest railway tunnel, Bukit Berapit Rail Tunnel. It is situated on the outskirts of Bukit Berapit in Perak, Malaysia. It's a component of the electrified double monitoring project Ipoh-Padang Besar. The tunnel was designed like several tunnels as an alternative to the ancient winding paths. When the tunnel was finished, the Berapit Bukit was closed. The tunnel stretches 2.9 km from the northern to the southern town of Perak, Changkat Jering. Its path passes twice through the federal road, two rivers, and the North-South Expressway through two micro bridges, one with a low overload. The tunnel construction began in 2008 and was finished in 2013. The project is now in service and has been established.

Public transport is commonly playing an important role in economic development in Malaysia especially in railway transportation apart of other public transport including bus, taxi etc. The service quality and the safety of transportation facilities must be in good condition to encourage peoples in using the public transport. Today, railway transportation is a popular choice for people to move around due to the speed and timeliness. Talk about safety, Malaysian does not have any specific standards for railway station especially standard for fire safety in tunnel structures. Currently, Malaysian using the mixed standards when develop the new railway system. Usually, contractors

appointed by government will use mixed standard with minimum cost as long comply with the contract. Without any specify standards for references, rescues operation having difficult situation to rescue people especially in tunnel because is no escape plan for passengers. Although the existing guidelines such as Malaysian Standard, UBBL related document and other authority department such as FRDM, SPAD, DOSH, OHSAS etc, the reference are too general and not enough and not specific for rail tunnel fire safety.

The tunneled line with a low overload on the North-2.1 operating North-South Drainage Crossing is in dispute with the twin 3m by 3m in a cross-sector bottom of the highway used to flow from a river and many streams. The tunneled line is a cross-traffic tunnel, where soil tests have shown that the 3m three-cell drainage tap has to be demolished and replaced to construct the twin-boor railway tunnel for the current drainage tap. Drainage and North-South Expressway, only in alluvial soil, have shown that the box culvert should be re-engineered for the expressway overpass. In the year 2035-37, the tunnel is projected to operate by a maximum of 153 trains a day. This tunnel has a maximum operating speed of 142 km / h and 92 km / h. A triple cell with each 3 m diameter pipe has been built with boreholes, showing no granite formation on the highway. On the other hand, the current guide can only be an expressway overpass by 4 m overlying from the top of the twin-bore rail tunnel. The building is carried out in a series from the floor base to the stations on the ground's surface to the signaling systems, using a multilayer construction method. In all four states, this method allows for simultaneous building. With the 3m diameter triple-layer drainage, which is now ready to substitute the 3 m twin box, the old drainage crossing for the Bukit Berapit tube, the demolition is ahead. It is now ready to replace the twin box of 3 m. However, the current

framework below the road barrier is to be demolished step-by-step and primarily to eliminate the steel bar reinforcement at the wall surface and the tunnel base.

Table 1.1 : Bukit Berapit Tunnel Characteristics

No	Description	
1	Length	*3.3 KM*
2	No. of Bores	*Twin bore tunnels running in parallel, single track*
3	Construction	*470000 hours, 80% by drill+blast with the balance by cut-and-cover.*
4	Arch	*Each arch comprised steel pipes of 6m long x 780mm diameter x 10mm wall thickness welded together for each 90-92m long drive (Fig 1.1)*
5	Spacing of cross passenger	*350 metre*
6	Walkway along the tunnel	*1.2 metre width along the tunnel*
7	Width of cross passenger	*2.4 metre*
8	Fire Rating of cross passenger	*2 hours*
9	Tunnel control building	*At Padang Rengas Portal (Fire main control room)*

Halcrow Pacific Pty constructed a tender design for the two double single-track tunnels: Berapit 2560m long, and Larut 400m long. The tunnels have a 42m net surface, the large spells with low overload are characteristic of the Berapit tunnel alignment. Conventional and mechanized excavations are envisaged, but the traditional pit is best developed in the contract documentation. The line goes under state highways as well as a rail tunnel. The bar is not accessible.

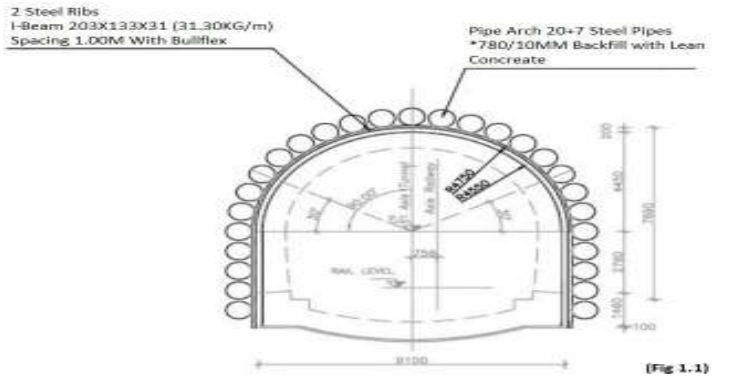

Figure 1.1: Bukit Berapit Tunnel Cross Section

Fire Protection System & Measures:

- Fire Hydrant/ standpipe
- Linear Detector System
- Jet Fan System
- The lighting of the emergency tunnel
- Pressurize System at cross way tunnel
- Emergency Communication System
- Fire Extinguisher in the train/ tunnel

1.2 PROBLEM STATEMENT

Fire is a significant danger to human life in the tunnels. Rail tunnel fires are uncommon occurrences, and rail tunnels typically require substantial investments in providing fire protection. It is necessary to understand the reasons for the first consideration of such fire safety. Tunnel fires also cause significant damage to the ecosystem. Small escape facilities and challenges the interveners face in entering the tunnel fire call for detailed, mutually agreed protection arrangements. If tunnels such as Bukit Berapit High-Speed Rail Tunnel are considered, they typically involve roads and rail. However, the word tunnel usage can be somewhat misleading as the following details can also refer to footpaths, subway stations, underground parking, etc. Since this rail tunnel is the first project in Malaysia and does not have a local standard, a lot of attention needs to be paid to fire prevention, such as stability, integrity, and structural evaluation during fires and firefighting systems' reaction. Two factors will be focused primarily on: a passive fire protection system and an active firefighting system to study the fire safety concept's efficacy for the Bukit Berapit tunnel. Inactive fire-fighters include smoke management system and the ventilation system for the fire, exit door, ventilation, internal decoration,

over-fire, etc. In the meantime, an active fire combat system includes sprinklers, detectors, hose rollers, moisturizers, etc.

According to Railway Investigation Branch (RAIB) record in ten years, the major cause of fire incident in the train tunnel is due to failure of electrical system. Beside that, cause of major fatality in fire incident is due to inhalation of smoke and trap in train because failure of door system.

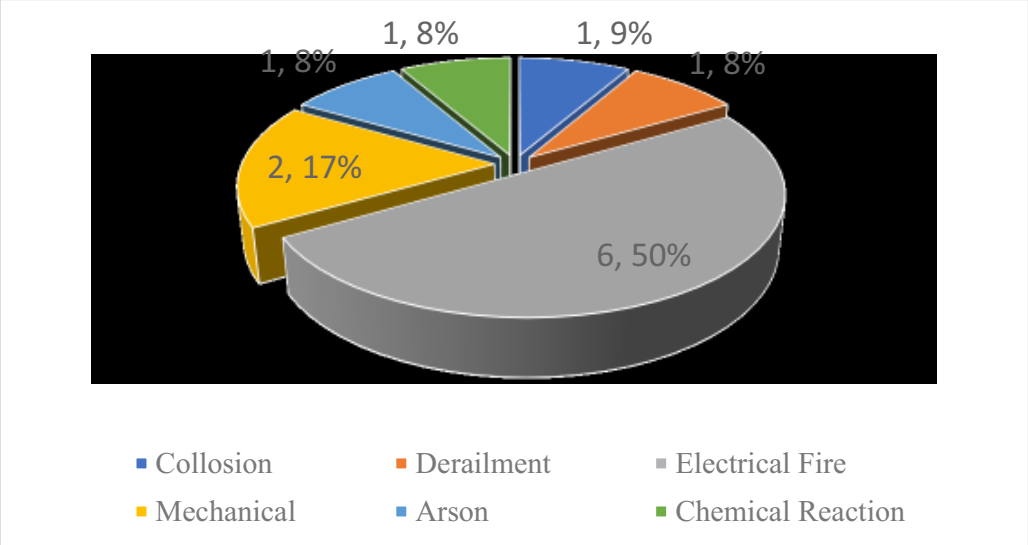

Figure 1.2. Causes of Fire In Train Tunnel

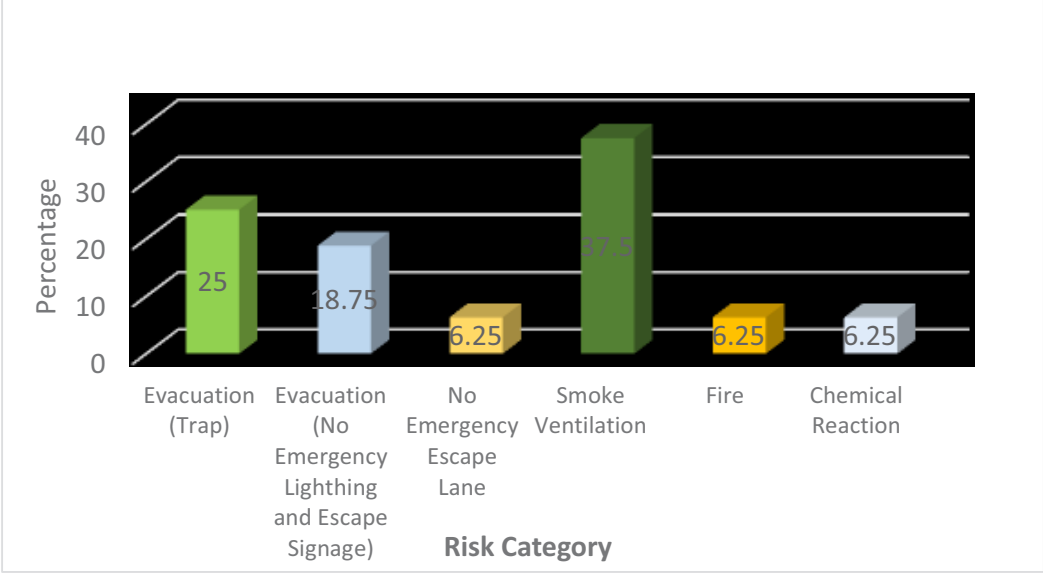

Figure 1.3. Statistic on Causes of Fatality/Injury

The purposes to study on railway technical standard are to explore and identify the suitable standard used for fire safety purpose. Also meet and to be compliant with fire-fighting equipment for fire safety in tunnels. Multiple standards were used in Malaysian railway and in term of requirements in the tunnel also different standards are used. For example, National Fire Protection Association for Hydrant System is useful in tunnels, but China TB Standard says it is not necessary. Also same for ventilation and detection system, some other standards say it is necessary and some standards not necessary. In such circumstance it is necessary to establish railway technical standard on tunnels in future railway development or construction.

1.3 RESEARCH OBJECTIVES

This study demonstrates some aspects of the holistic approach needed to achieve a high and sustainable underground infrastructure safety level. This analysis's primary purpose is to examine the fire protection system's efficiency in Bukit Berapit Tunnel by:

i. To explore the knowledge and exposure on fire safety in the railway tunnel.

ii. To identify suitable standard and fire safety measures used in managing fire safety for railway tunnels.

iii. To establish local standard for fire safety in railway tunnels structures.

1.4 RESEARCH QUESTIONS

This study is conducted to answer the following questions:

i. What is the level of knowledge and exposure on fire safety in the railway tunnel?

ii. How the implementation and monitoring of Fire Safety Risks in Rail Industry Construction Projects?

iii. What are the initiatives in Developing Fire Safety Standards for the Development of Rail Industry Construction Projects in Malaysia?

1.5 SIGNIFICANCE OF RESEARCH

This report offers an overview of fire safety studies from the viewpoint of fire protection in underground road and rail tunnels. The efficiency of Bukit Berapit Rail Tunnel Fire Protection. The key areas are the construction of fires, structural safety, smoke control, and fire detection by Photoelectric or Optical Detection systems based on heat/smoke or water. We are introducing the current Bukit Berapit Trail Tunnel Safety Standard operational procedures.

The following are possible benefits of this research to the industry:

i. This research can be used for selection the best firefighting system either passive or active system for train tunnel via development of new local standard. This systems shall be achieved through a composite of facility design, operating equipment, hardware, procedures, and software subsystems that are integrated to provide requirements for the protection of life and property from the effects of fire. (clause 4.1.1 Fire Safety of system, NFPA130, "Standard for Fixed Guide Transit and Passenger Rail Systems 2014 Edition", National Fire Protection Agency, 2014.

ii. As a guidance to professional to standardize design, construct accordingly and maintain the system in the tunnel in Malaysia. Uniform Building By-Law (UBBL), clause 25, Certificate of completion and compliance",1984.

iii. The hazards identified by this research in the Bukit Berapit tunnel, along with its recorded analytics may help Keretapi Tanah Melayu Berhad (KTMB) and the Fire and Rescue Department to formulate a set of strategies that are more effective in handling fire incidents in the tunnel (Chow, W., & Qu, L. (2013). Fire hazard

assessment for a green railway station. Fire And Materials, 38(4), 451-461. doi: 10.1002/fam.2189.

iv. The findings in this research may be used to advise and update on the future revisions of HIRARC by DOSH Malaysia in assessing the safety in Malaysian rail tunnel systems. (Guidelines on Occupational Safety and Health in Tunnel Construction, Industrial Health Division, Department of Occupational Safety and Health Ministry of Human Resources Malaysia, OHSAS 18001, July 1998).

v. The findings of this research may help in updating the standards set for Tunnel Safety by the Department of Standards under the Ministry of International Trade and Industry (MITI) Malaysia. DSM function is to develop market-relevant Malaysian Standards across all sectors through consensus to ensure quality, safety & environmental protection as well as to gain global competitiveness for the industry at large." ('MS Development Process' from The Official Website of Department of Standards Malaysia, 2014).

1.6 SCOPE OF RESEARCH

There are a lot of considerations when it comes to tunnel safety, and rather than analyse every aspect of the hazard control installations of the Bukit Berapit tunnel, this research will focus on the Tunnel Safety Operational System and assess its readiness to respond to fire incidents and emergencies. The study will concentrate on and respond to Tunnel Fire Safety, Tunnel operations, and emergency planning.

1.7 TERMS AND DEFINITIONS

Railway tunnel is a type of multipurpose tunnel created, built, designed, constructed, maintained and upgraded to allow a variety of size of train and other types of rail transport

to travel through mount, hills, sea and river with various purpose. (according to Prof. A. Balasubramanian, Centre for Advanced Studies in Earth Science, University of MYSORE, India-Slide Presentation 31 Julai, 2017).

Fire Safety according to NFPA 550 is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts.

Within the scope of this research, three types of firefighting systems will be taken into consideration. They are:

i. Passive Firefighting System is a set of components that are always on and requires no action to be activated when a fire incident occurs within the premise of its installation such as walls, floors, sheets and containment boxes (to protect important equipment on the premise). (uniform Building by Law (UBBL) 1084 Amended 2012 clause 133-Defination).

ii. Active Firefighting System is a set of components that requires action to be activated when a fire incident occurs within the premise of the installation such as water sprinklers and fire alarms.). (uniform Building by Law (UBBL) 1084 Amended 2012 clause 133-Defination)

iii. Local Standard is a document gazetted and approved to be use in a country and bound with national law, rules, and regulation. A standard is a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons.

REFERENCES

American Society of Civil Engineering, *Automated People Mover Standard.*

Amberg Engineering Ltd, Regensdorf-Watt, Switzerland, "*Civil Engineering Constraints on Tunnel Ventilation and Safety*", M. Bettelini, A. Arigoni & S.S. Saviani.

Beard, A., & Carvel, R. (2012). *The handbook of tunnel fire safety. London: ICE.*

Beji, T., Ukleja, S., Zhang, J., & Delichatsios, M. (2012). *Fire behavior and external flames in the corridor and tunnel-like enclosures. Fire and Materials*, 36(8), 636-647. doi: 10.1002/fam.1124.

British Standard (BS 6164), "*Code of Practice for Health and Safety in.*

China Communications Construction Company (CCCC) Sdn. Bhd., "*East Cost Rail Link, (ECRL) Fire*".

Chinese Railway Standards & Codes, "*TB10020:2017, TB10068:2010 & TB10003:2005*".

Chow, W., & Qu, L. (2013). *Fire Hazard Assessment for A Green Railway Station*. Fire and Materials, 38(4), 451-461. doi: 10.1002/fam.2189

Department of Occupational Safety and Health (DOSH) Act 1994,"*Occupational Safety and Health*", Act 514.

Dexalon Sdn. Bhd., Safety Design Philosophy Report Phase 1 – "*GentingTunnel; Peer Reviewer Report*", Mott MacDonald

Ejrup, A. (2012). *Towards Design Options and Trade-offs for Road Tunnels Incorporating Suppression Systems. Fire Technology,* 50(3), 545-563. doi: 10.1007/s10694-012-0313-6.

European Commission, "*96/48/EC COUNCIL DIRECTIVE of 23 July 1996 on the Interoperability of the Trans-European High-Speed Rail System*," Off. J. Eur. Union, 1996.

European Commission, *"Commission Decision of 20 December 2007 concerning the technical specification of interoperability relating to safety in railway tunnels in the trans-European conventional and high-speed rail system"*, 2008/163/ EC, 2008.

Euro-Transport, Issue 5, *"Improving Road Tunnel Safety"*, F. Tarada, 2007.

Falendysh, A., Chigiry, N., & Kosarev, O. (2018). *Automated System of Selection Multiple Units Rolling Stock Rolling Stock for Conversion to Hydrogen Fuel. Collected Scientific Works of Ukrainian State University of Railway Transport*, 0(175). doi: 10.18664/1994-7852.175.2018.127030.

Fridolf, K. (2015). *Rail tunnel evacuation. Lund: Division of Fire Safety Engineering, Faculty of Engineering*, Lund University.

Fridolf, K., Nilsson, D., & Frantzich, H. (2011). *Fire Evacuation in Underground Transportation Systems: A Review of Accidents and Empirical Research. Fire Technology*, 49(2), 451-475. doi: 10.1007/s10694-011-0217-x.

Fu, M. (2013). *Mode Selection of Railway Passenger Dedicated Line Transportation Organization Based on Analytic Hierarchy Process. Advanced Materials Research*, 694-697, 3314-3320. doi: 10.4028/www.scientific.net/amr.694-697.3314.

Gehandler, J., Eymann, L., & Regeffe, M. (2014). *Limit-Based Fire Hazard Model for Evaluating Tunnel Life Safety. Fire Technology,* 51(3), 585-614. doi: 10.1007/s10694-014-0406-5.

Guidelines on Occupational Safety and Health in Tunnel Construction, Industrial Health Division, Department of Occupational Safety and Health Ministry of Human Resources Malaysia, *OHSAS 18001, July 1998.*

Guidelines on Occupational Safety and Health in Tunnel Construction, Industrial Health Division, Department of Occupational Safety and Health Ministry of Human Resources Malaysia, *OHSAS 18001, July 1998.*

High Speed Europe, "*European Union*", ISBN 978-92-13620-7.

Ingason, H. (2012). *Guest Editorial Fire Technology. Fire Technology*, 49(2), 433-434. doi: 10.1007/s10694-012-0268-7.

International Union of Railways 779-9, UIC in French: "*Union Internationale des Chemins de fer*".

ITA-AITES, WTC2020, *"Innovation and Sustainable Underground Serving Global Connectivity",* (wtc2020.my/4/638/tunnelling-in-Malaysia/).

Khattri, S. (2017). From small-scale tunnel fire simulations to predicting fire dynamics in realistic tunnels. Tunneling And Underground Space Technology, 61, 198-204. doi: 10.1016/j.tust.2016.10.010.

Klein, R., Maevski, I., Bott, J., & Calado, A. (2020). Estimating water density for tunnel fixed firefighting system and ventilation requirements to control fires in road tunnels. Fire Safety Journal, 103180. doi: 10.1016/j.firesaf.2020.103180

Ko, Y., & Hadjisophocleous, G. (2013). Study of smoke backlayering during suppression in tunnels. Fire Safety Journal, 58, 240-247. doi: 10.1016/j.firesaf.2013.03.001.

Klein, R., Maevski, I., Bott, J., & Calado, A. (2020). Estimating water density for tunnel fixed firefighting system and ventilation requirements to control fires in road tunnels. Fire Safety Journal, 103180. doi: 10.1016/j.firesaf.2020.103180Li, L., & Zhao, L. (2011). Numerical Simulation for Smoke Flow of the Underground Railway Tunnel Fire. Advanced Materials Research, 368-373, 1454-1457. doi: 10.4028/www.scientific.net/amr.368-373.1454.

Land Public Transport Act 2010, "*Railway Entity is the Railway Company andLicensed Operator*", Act 139, Act 714, Act 715.

Li, Y., & Ingason, H. (2013). Model scale tunnel fire tests with automatic sprinkler. Fire Safety Journal, 61, 298-313. doi: 10.1016/j.firesaf.2013.09.024.

Li, Y., & Ingason, H. (2020). Parametric study of design fires for tunnels with water-based fire suppression systems. Fire Safety Journal, 103107. doi: 10.1016/j.firesaf.2020.103107.

Liu, Y. (2013). *Study on Structure Safety of the Tunnel Secondary Lining of Passenger Dedicated Line for High-Speed Railway during Service Period. Advanced Materials Research*, 724-725, 1689-1692. doi: 10.4028/www.scientific.net/amr.724-725.1689.

Malaysian Standard (MS1513), "*Packaging – Transportation of DangerousGoods*", 2003, Malaysia.

Malaysian Standard (MS1722), "*Occupational Health and Safety Management Systems*", 2011, Malaysia.

Malaysian Standard, (MS 2363), "*Work in Tunnelling – Code of Practice*",2010, Malaysia.

Mawhinney, J. (2011). Fixed Fire Protection Systems in Tunnels: Issues and Directions. Fire Technology, 49(2), 477-508. doi: 10.1007/s10694-011-0220-2

Meng, Q., Qu, X., Wang, X., Yuanita, V., & Wong, S. (2010). *Quantitative Risk Assessment Modeling for Nonhomogeneous Urban Road Tunnels. Risk Analysis*, 31(3), 382-403. doi: 10.1111/j.1539-6924.2010.01503. x.

NFPA130, *"Standard for Fixed Guide Transit and Passenger Rail Systems2014 Edition"*, National Fire Protection Agency, 2014.

North American Tunnelling 2008 Proceedings, "*Overview of NFPA502 Standard for Road Tunnel, Bridges and Other Limited Access Highways*" Edition 2008, W. Connell and J.R. Gamache.

NRC Publications Archive, "*International Tunnel Fire-Safety Design Practices"*, Miclea, P. C; Chow, W. K; Shen-Wen, C; Junmei, L; Kashef, A; Kang, K.

Nyman, H., & Ingason, H. (2012). Temperature stratification in tunnels. Fire Safety Journal, 48, 30-37. doi: 10.1016/j.firesaf.2011.11.002.

Peng, L. (2014). *Existing Operational Railway Tunnel Water Leakage Causes and Remediation Technologies. Advanced Materials Research*, 1004-1005, 1444-1449. doi: 10.4028/www.scientific.net/amr.1004-1005.1444.

Rabani, M., & Faghih, A. (2015). *Numerical analysis of airflow around a passenger train entering the tunnel. Tunnelling and Underground Space Technology*, 45, 203-213. doi: 10.1016/j.tust.2014.10.005.

Ramachandran, G. (2020). Quantitative Risk Assessment in Fire Safety. Routledge.

Ryu, J., & Shin, H. (2016). A Numerical Study on Effects of Fire Safety by Smoke Ventilation Velocity at Railway Tunnel in Fire. Journal of Korean Society of Hazard Mitigation, 16(2), 83-89. doi: 10.9798/kosham.2016.16.2.83.

Sarvari, A., & Mazinani, S. (2019). A new tunnel fire detection and suppression system based on-camera image processing and water mist jet fans. *Heliyon*, *5*(6), e01879. doi: 10.1016/j.heliyon. 2019.e01879.

Shabrov, S. (2018). Ensuring Fire Safety on Traction Rolling Stock of Traction Rolling Stock Directorate and Analysis of The Causes of Fire. Technology of Technosphere Safety, 80, 36-45. doi: 10.25257/tts.2018.4.80.36-45.

Schoonbaert, L., & Eeckhaut, S. (2015). *Realisation of fire and intrusion protection at the "Diabolo" train tunnel complex at Brussels Int'l Airport*. Case Studies in Fire Safety, 3, 25-35. doi: 10.1016/j.csfs.2015.02.001.

Sui, C., Zhou, X., & Wang, L. (2013). *The Comparison of Tunnel Engineering Construction Methods for Rehashing Tunnel Crossing Underneath Existing Tunnel on Lanzhou-Chongqing Railway. Applied Mechanics and Materials*, 405-408, 1330-1333. doi: 10.4028/www.scientific.net/amm.405-408.1330.

Safe & Reliable Tunnels – Innovative European Achievements, *Guidelines forFire Safe Design: Synthesis and Current Harmonisation Processes*", Didier Lacroix, Centre d'Études des Tunnels (CETU), France.

SCOR Global P&C, "*Fire Protection in Tunnels – Focus on Road & Train Tunnels*", Technical Newsletter, July 2014

The Department of Environment (DOE), "*Section 34A(2c), Rules, RegulationsOrders and Guidelines*", Environmental Quality Act, 1974

The Handbook of Tunnel Safety, "*A History of Tunnel Fires*", ISBN: 0 7277 3168 8 (2005).

Transportation Research Record – Environment, Planning and Climate Change; *"Security and Safety of Rail Transit Tunnels"*, Anna M. Rakoczy, Stephen T. Wilk and Mary Clara Jones.

Technical Specification for Interoperability (TSI) 2014, "*Safety in Railway Tunnels at Europe Country*", European Union.

Tomar, M., & Khurana, S. (2019). *Impact of passive fire protection on heat release rates in road tunnel fire: A review. Tunnelling and Underground Space Technology*, 85, 149-159. doi: 10.1016/j.tust.2018.12.018.

Undang-Undang Malaysia, Akta Perkhidmatan BOMBA 1988, "*Fire Service Act 341*".

Uniform Building By-Law (UBBL), "*Part 7 (Fire Requirements) and Part 8 (Fire Alarm, Fire Detection, Fire Extinguishment and Fire Fighting Access)*",1984

UK Safety Railway Principle and Guidance, "*Part 2 – Infrastructure, 74(c)*", Tunnelling in the Construction Industry, 2011, United Kingdom

Weidmann, U., Kirsch, U., & Schreckenberg, M. (2014). *Pedestrian and evacuation dynamics* 2012. Springer Science & Business.