Metro Red Line/Purple Line Familiarization Training

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Abstract

Familiarization training of first responders in metro subways is quintessential for strengthening their occupational performance. However, the effectiveness of responders' training is determined by the availability and diversity of training resources. In this study, the Los Angeles County Metropolitan Transportation Authority's (*Metro*) *Red Line/Purple Line* fire life safety systems and facilities were evaluated to determine their adequacy in supporting responders' familiarity training to prepare them for emerging fire risks and evacuation needs. The study analyzed the effectiveness of the line's fire life safety systems and facilities on responders' familiarity training on the aspects of cognitive fluency, prototypicality, and habit. It was established that the fire safety tools, facilities, and technologies employed along the line have the potential to provide responders with immersive - interactive/engaging learning that put learners at the center of the learning experience - and non-immersive - a learning experience in which learners do not participate in the learning environment such as desktop-based learning - experiences with a substantial effect on their occupational performance.

Keywords:
Vehicle safety, stations & facilities, mezzanine level, familiarity training, cognitive fluency, prototypicality, ventilation systems.

1. Introduction
Fixed guide way transit and passenger rail systems are efficient means of transporting a large population of passengers. Codified fire safety standards specific to fixed guide way transit and passenger rail systems, however, are less than 40 years old (Devlin, 2014).

Subway systems in Boston, New York, London, and Paris have been in continuous operation for more than 100 years. The metro is currently constructing an extension of the 16 station Purple Line from Wilshire/Western **(Figure 1)** to the Westside of Los Angeles, terminating at Westwood/Veteran's Administration Hospital **(Figure 2)**. The nine-mile extension will include seven stations and is expected to begin its revenue operations in 2023. The Purple Line project is fitted with advanced fire life safety systems, technologies, and facilities which ultimately give it a competitive edge over other lines in terms of fire mitigation, effectiveness and efficiency of emergency evacuation, and familiarity training of responders. The line has not experienced any fire safety system activation incidence since it operationalization. However, it offers responders a new platform for familiarity training and advanced preparation for fire evacuation. This study explores and analyzes how the fire safety tools, technologies, and facilities installed on the Metro Red Line/Purple Line enhances the familiarity training - cognitive fluency, prototypicality, and habit - of the first responders compared to the older lines.

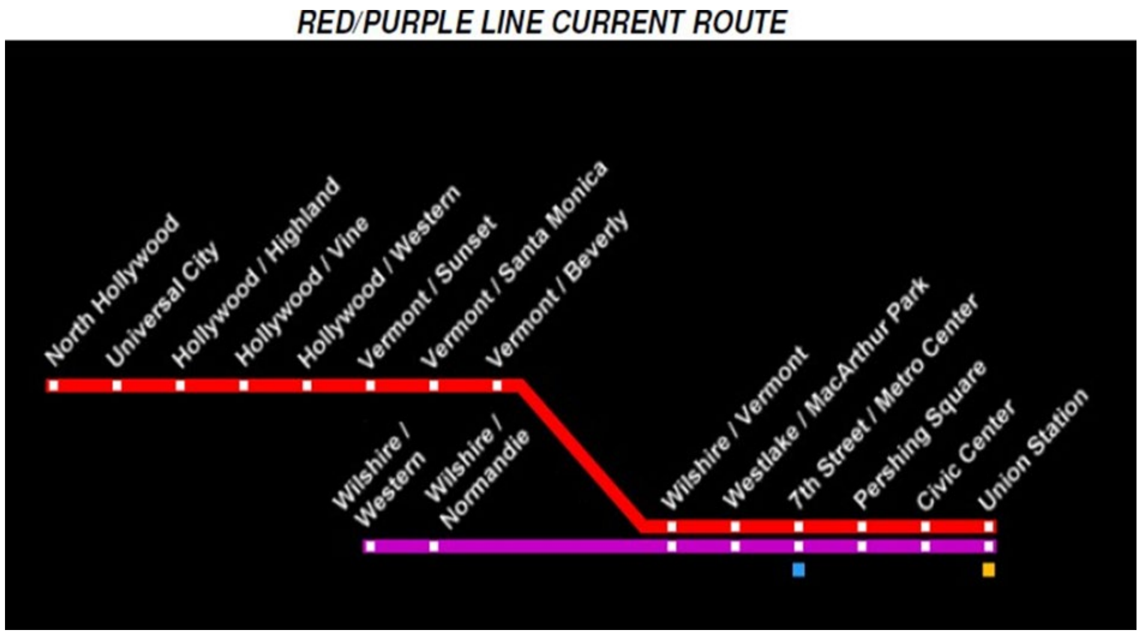

Figure 1: Current route of the Red/Purple line.

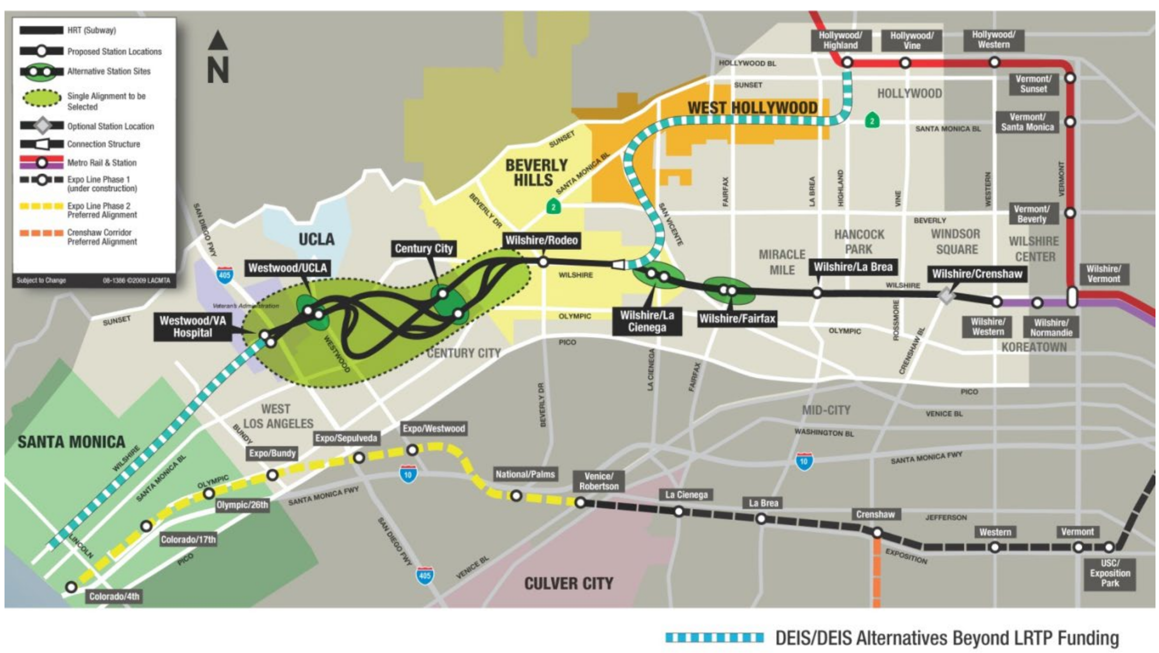

Figure 2: Map showing the extension of the Purple Line project.

2. Objectives

1. To investigate and identify fire/life safety features installed on Los Angeles County Metropolitan Transportation Authority's (Metro) Red Line/Purple Line.
2. To explore and analyze the impact of Los Angeles County Metropolitan Transportation Authority's (Metro) Red Line/Purple Line on the familiarization training of first responders' emergency evacuation performance.

3. Literature Review

Fire evacuation efforts from Metro accident scenes are complex processes compounded by enclosed space, limited exits, and overcrowding. The evolution and propagation of fires in typical subways follow a dynamic path characterized by complex head fire rates, flame geometry, and temperature-time curves. Understanding the dynamics of fire evolution mechanisms and propagation behavior is essential in managing the fire evacuation processes in underground metros. In Wu et al. (2018), the Delphi method and Bayesian network were employed successfully to model the dynamic behavior of subway fires. Twenty-eight Bayesian network nodes and numerous other child nodes were evaluated and analyzed to determine their individual and collective contribution to the initiation and propagation of metro fires.

The Bayesian framework proposed by the researchers allows a quantitative analysis of risk distribution in subway environments. The overall insight of fire propagation behavior provided by the model has the potential to guide emergency response and limit functional interruption of the metros and infrastructural damages. In wang et al. (2021), the dynamics of fire and smoke propagation were modeled using the Bernoulli equation's unsteady flow theory. A numerical simulation was employed to analyze the static and kinetic behavior of smoke distribution in a tunnel and the influence of metro train piston wind. The results of the simulation observed that piston wind has a statistically significant influence on the propagation and distribution of fire smoke inside the metro tunnels. The key findings of the study suggest the direction of longitudinal ventilation relative to that of the piston has substantially influenced the controllability of smoke fire.

Retrospectively, piston wind flow in the direction of the ventilator enhances its smoke fire control effect significantly. On the other hand, the flow of piston wind in the opposite direction limits the smoke control capacity of the longitudinal ventilation. The flow of the piston wind generates horizontal inertia force and vortexes which breaks smoke strata leading to the distribution of toxic fumes in the tunnel. Wang et al. model of smoke fire control in metro tunnels offers first responders' valuable information on the management of smoke in enclosed spaces which is critical for limiting the spread of fire and number of casualties. Generally, the dynamics of smoke and thermal propagation in underground tunnels are largely defined by their geometrical and ventilation parameters and the characteristics of fire.

Papakonstantinou et al. (2021) using the fire dynamic simulation and the fractional effect dose demonstrates that the geometry of the tunnel, quality and architecture of ventilation, and heat release rate maximum, and fire curve determines the propagation and distribution of smoke and fire in metro tunnels. The general conditions of the tunnel are largely defined by the chemical composition of the burning materials and the nature of burning. In this case, passengers' exposure to fractional effective dose is determined by the level of carbon dioxide concentration in the air, heat temperature, and visibility conditions.

The response performance of first responders depends on human, fire, and building features of the metro tunnel. Failure to integrate and exploit these features in fire emergencies has the potential to devastate the operation of the metro system and lead to unnecessary loss of lives. The effectiveness of the fire evacuation strategies relies on factors unique to the fire accident and the decision-making skills of the first responders. Chen et al. (2017) multiagent-based and M/G/C/C simulations of strategies, factors, and bottlenecks that influence fire evacuations in metro stations demonstrated that individual characteristics, the number of evacuees, the capacity of the safety facilities, evacuation route, evacuation terminus, and evacuation strategies determines the effectiveness of the process.

The nature and behavioral characteristics of the evacuation landscape are affected by several factors including the physiology and psychology of the responders and evacuees, the emotional state of the evacuees, and the density of the crowd (Harding et al., 2011; Xiao-xia et al., 2011). The correlation between the effectiveness of the evacuation process and the psychological and emotional state of the people involved in the process is modulated by the capacity of the safety facilities – escalators, staircases, connecting corridors, and other exit routes –and environmental conditions (Wang & Song, 2020; Li et al., 2012). Overcrowding emergency exit routes and facilities complicates the evacuation process by increasing risks of stampedes, chaos, and poising by toxic fumes. Evacuation models are fundamentally simulations of crowd behavior and the dynamics of directing them away from imminent dangers and harms (Long et al., 2020). In this regard, a complete understanding of evacuees' behavior and tools available to facilitate the process in metro tunnels impacts responders' evacuation performance, speed, critical thinking, and decision-making.

Optimal design of evacuation paths complements mechanical ventilation which promotes the management of walkway flow during the emergency evacuation. In pan et al. (2019), multi-agent simulation of walkway design parameters indicates that increasing the width of the safe paths lowers the unidirectional and bidirectional evacuation times by 54.5% and 35.2% respectively. Availing safety tools in subway tunnels and familiarizing emergency evacuation personnel with the overall safety and security conditions of the accident environment goes a long way in alleviating the deterioration of fire incidences. Safety standards demand subway tunnels and coaches to utilize non-toxic fire-resistant materials, installation of adequate ventilation, proper training of employees' ventilation practices, maintain optimal linkages between tunnels and emergency routes, and regular contacts between emergency responders and subway agencies. However, there is a substantial knowledge gap on how the familiarization of first responders with fire life safety systems and facilities of the metro's subway system influence the evacuation performance of the first responders. In this study, the familiarization of the first emergency responders to the fire life safety systems and facilities installed along the Metro Red Line/Purple Line is used to evaluate and analyze how it influences their fire evacuation performance.

4. Methods and Analysis

The study employed a case study to investigate and evaluate the adequacy of the fire management systems, facilities, and technologies in enhancing the familiarity training of responders (Devlin, 2014). The effectiveness of the line on responders' training was measured on three parameters including cognitive fluency, prototypicality, and habit. The *Metro Red Line/Purple Line* used in the case study is designed to NFPA 130 *standard for fixed guide way and passenger rail systems.* NFPA 130 is an international fire safety standard widely used for design of transit systems. First published in 1983, it applies a holistic approach to life safety from fire protection requirements to include stations, trainway, emergency ventilation systems, vehicles, emergency procedures, communications, and control systems. NFPA 130 regulates through design selection, types of materials, materials fire properties (flammability, combustibility, and smoke production), and potential fire hazards. These regulations are intended to control and/or limit the likelihood of a fire's occurrence, its growth rate, and severity (Devlin, 2014). The Metro Red Line/Purple Line also conforms to Metro's Fire/Life Safety and Security Design Criteria, Building Codes and Fire Codes.

5. Results and Discussion

Familiarization Training will consist of the following systems and facilities in the *Metro Red Line/Purple Line* subway system:

1. **Passenger Vehicle Characteristics & Safety**

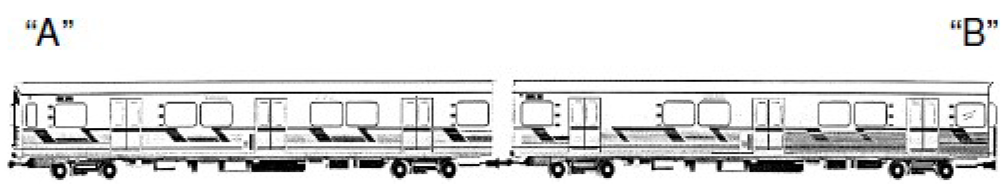

Figure 3: Schematic diagram of the *Metro Red Line/Purple Line* Passenger Vehicle

Metro has an active fleet of 104 passenger vehicles. The train configuration is set up with a minimum two-vehicle combination, which includes one "A" vehicle (with the controller's cab), and one "B" vehicle **(Figure 3)**, and up to six vehicles maximum. The vehicles can operate as dependent pairs and are assembled so that a cab is placed at each end of a train configuration to enable bi-directional travel. The train operator's cab has all of the controls necessary to operate a multi-car train. Further statistics include the following: The trains are propelled by four traction motors per vehicle, operated from 750 Volts direct current (VDC). Each train's power is supplied by the contact rail (third rail), which supplies all power for traction motors, converter (for charging on-board battery system), air compressor, heating elements, and air conditioning. In the event of loss of traction power, batteries provide power for the auxiliary systems, such as the train controls, doors, interior lights, and air conditioning system. The batteries are located under the "B" car and provide 37.5 VDC. A "disconnect switch" is located inside of the battery compartment. Each vehicle is equipped with and array of safety features and equipment **(Figure 4)**, including exit doors, external emergency door handle and crew switch, emergency ladder, designated incident command and crew stations, and two 10A/60BC fire extinguishers, located in the operator's cab and between the transverse passenger seats. There are two passenger intercom push button controls per vehicle for emergency communications with the train operator, who is separated from the passenger area in a secured cab.

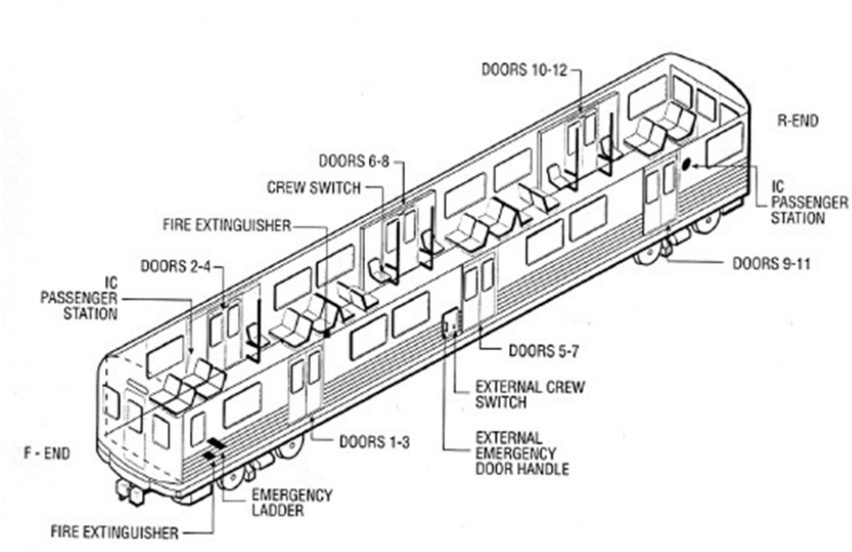

Figure 4: Schematic diagrams showing the safety features of metro car.

6. Stations and Facilities

A. Track Level Rooms – between cross-passages 48 and 49 (between Hollywood/Highland Station and Universal City Station). Knox-box located in cross-passage. Fire Control Panel (FCP) in Train Control and Communications (TC&C) rooms. The EMP control for this area is located at the EMP at Hollywood/Highland Station.

B. Mid-Vent Shaft – between cross-passage 65 and 66 (Between Universal City and North Hollywood Station). Access to these rooms from street level can be accomplished via the emergency Exit Hatch on the southeast corner of Lankershim Blvd and Hortense Avenue in the sidewalk in front of the North Hollywood Toyota Dealership. This area is controlled by the EMP at the North Hollywood Station.

6. Trainway Fire Safety – Platform Level

The train way typically serves as the means of egress for passengers in the event it becomes necessary to evacuate a train. In an enclosed trainway/tunnel, the means of egress includes enclosed exits and cross passages that serve as points of safety. The maximum distance between exits and cross passages permitted by *NFPA 130* is 2,500 ft. and 800 ft, respectively. In an urban transit system or intercity passenger rail system, the train population during peak period can be as many as 1,200 passengers.

7. Train Station – Mezzanine Level

Modern transit station design is a single volume space formed by the passenger platform and contiguous train way, possible intermediate mezzanine level(s), and continuous connection to the street level above. Modern stations often include extensive use of escalators and elevators for efficient passenger movement. The Mezzanine level is the first level below ground, which is the public access level to the tunnel. In some stations, an ancillary level may be encountered as the first level below the street. The ancillary level is not for public access and can only be entered by using keys found in the Fire Department's lock box, adjacent to the EMP.

The TC&C room contains vital monitoring equipment, including the fire alarm panel, methane detector, and communication equipment (the reset of fire alarms is conducted in this room). The DWP power station room is energized with 34,500 volts and should not be entered by Fire Department personnel. The valve rooms will contain selected isolation/shut-off valves for the combination standpipe/sprinkler system. The EMP is located on the wall in the Mezzanine Level **(Figure 5)** and is directly adjacent to a Fire Department lock box, containing keys to the EMP and all station sites. There are two types of EMP's in the system.

Figure 5: Photo of the new style EMP.

8. Train Station – Platform Level

The Platform Level is the area where passengers enter and exit trains. The basis of station platform design is the NFPA 130 requirement to evacuate all passengers from the platform in four minutes and to reach a point of safety within six minutes. Passengers can access this level by elevator, escalator, or stairs. Platform levels are designed to accommodate a six-car train (over 450 feet long). This level will have the Emergency Trip Station (ETS), an emergency equipment room, and access to the tunnels. There will be an ETS at each end of the station for each track, indicated by the Blue Light Station (BLS) on the wall.

Each ETS contains the following components:

No.	Component	Function
1	Emergency Telephone (ETEL)	To communicate with ROC or the EMP
2	Fire Department telephone (FTEL)	Used to communicate fire incidences.
3	A diagram	Indicates the section of track will be affected by the trip switch.
4	A deluge sprinkler control switch	To activate sprinklers under the trains in fire emergency cases.
5	A trip-switch	Disconnects power to a segment of the third rail

9. Train Station – Platform Level

The tunnels are designated “AL” or “AR” (L for Left, and R for Right) when looking at the tunnels from the Union Station (i.e., with Union Station at your back the “AL” tunnel lies on the left, and the “AR" tunnel is on the right). The only variance to this designation is in the 2B tunnel segment from Wilshire/Vermont to Wilshire/Western, where the tunnels are identified as “BL” and “BR.” The map in the ETS will indicate where you are and which tunnel the ETS is located in. Some of the tunnels may have a sign indicating tunnel identification, at the end of the platform above the tunnel access to Cross Passages.

In the event of any possible tunnel evacuation, there are a total of 93 cross passages staggered at approximately 750-foot intervals throughout the tunnel **(Figure 6)**. These cross passages are used for the transfer of passengers or emergency responders from one bore to another. Some cross passages also lead to emergency exits to street level. All cross passages include a BLS with an ETS to de- energize a section of track, an Emergency Telephone (ETEL), a Fire Department telephone (FTEL) and a 2-½ inch Fire Department Connection (FDC).

TUNNEL CROSSPASSAGE

Figure 6: Photo of Red/Purple Line tunnel cross passage.

A. Emergency Exits

There are emergency exits throughout the entire system. Emergency exits can be accessed from track level, platform level, mezzanine and ancillary levels. Exits with RED signs will not exit to street level. GREEN exit signs indicate street level egress and may exit via an emergency escape hatch. Emergency escape hatches have panic hardware on the inside and an access door on the outside **(Figure 7)**, which may be opened with a hydrant wrench. Hatches are connected to an intrusion alarm, which will display on the EMP and at the ROC.

EMERGENCY ESCAPE HATCHES

Figure 7: Photo of Red/Purple Line emergency escape hatches.

B. Emergency Walkway

There is a walkway area on one side of the track, throughout the Red Line system on both bores of the tunnel to allow emergency personnel access to equipment and trains **(Figure 8)**, and to off-load passengers in cases of extreme emergencies.

TUNNEL WALKWAY

Figure 8: Photo of Red/Purple Line tunnel walkway.

10. Communications

There are various ways to communicate in the tunnel **(Figure 9)**. The EMP panel has an ETEL, FTEL, and a public address system, which may also be used by ROC to communicate remotely to stations. Public telephones are located on the mezzanine levels. Additionally, public cell phone conduit is being installed in Metro tunnels; with full underground reception available to patrons by 2016.

11. Fire Protection/Water Systems

NFPA 130 station fire strategy is to manage fire impact and controlling the fire in ancillary spaces by means of fire barriers and automatic sprinkler systems. Sprinklers protect all public and ancillary areas of the station. Sprinkler Valve Rooms are located at each end of a station and are generally at the first landing passed the double doors at each end of a station platform

Figure 9: Photo of Red/Purple Line emergency telephone and hose cabinet.

A combined standpipe system is supplied by at least two 8-inch mains **(Figure 11)** and will have two Fire Department Connections per station. Fire Department apparatus augmenting the system should supply 125 psi.

A fire suppression Under-Carriage Deluge System **(Figure 10)** has been installed between the tracks at each side of all platforms on the Metro Red/Purple Line. Activation can be achieved by depressing the buttons contained with the ETS (Orange Box) located under a BLS at the ends of each station platform. When the under-carriage deluge buttons are depressed, the following occurs:

- First de-energize traction power to the side of the platform (allow the train to arrive at the station prior to activation).
- Activate the deluge system manually at the ETS.
- Fire Suppression water begins to flow through the plumbing, forcing out air in the piping downstream of the valve.
- Water is expelled upwards through the sprinkler heads under the train at the platform.

The deluge system is only activated manually, it does not activate automatically.

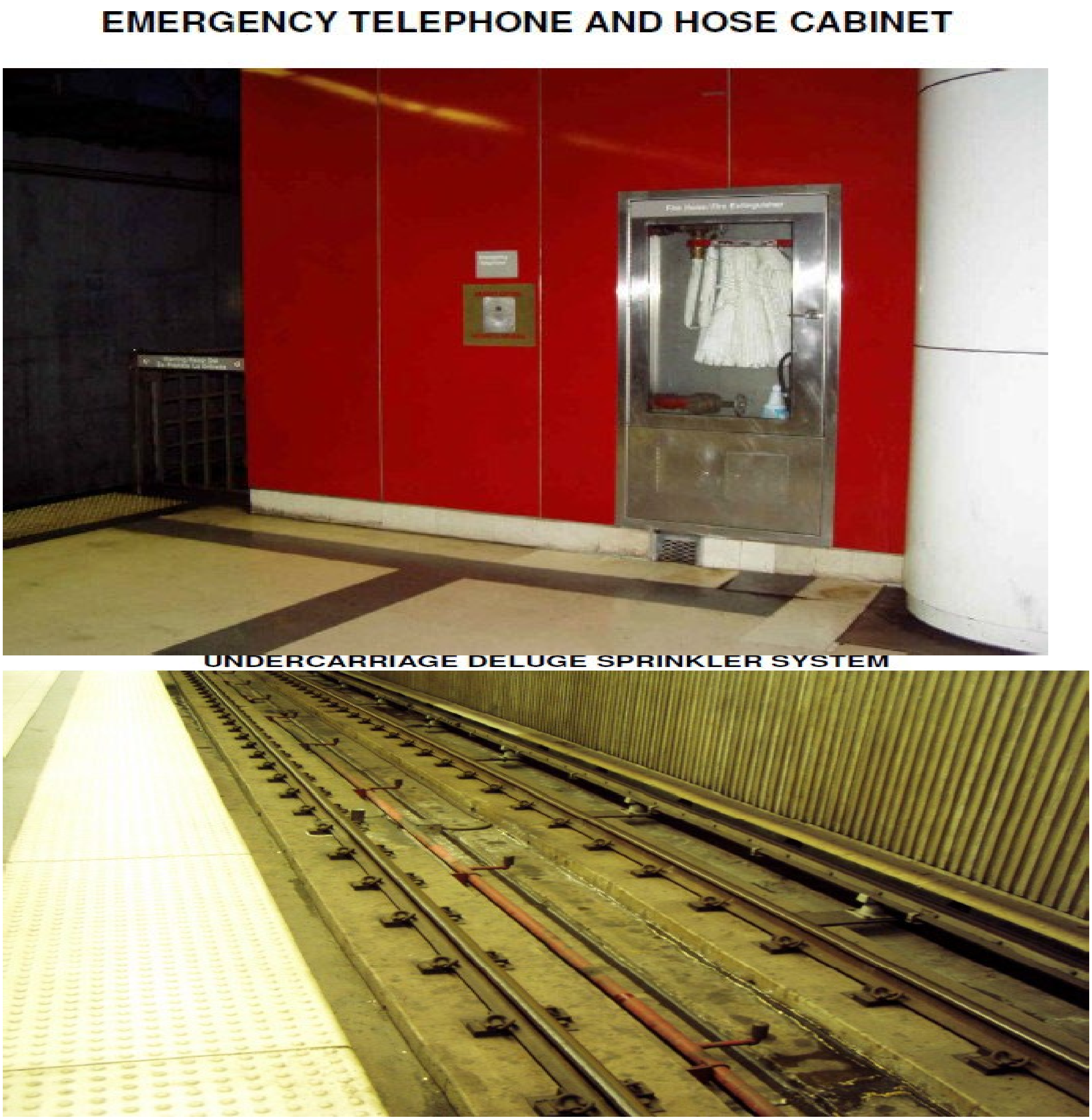

Figure 10: Photo of Red/Purple Line undercarriage deluge sprinkler system.

Figure 11: Photo of the Red/Purple Line tunnel standpipe.

12. Ventilation Systems

Emergency ventilation in enclosed stations serves to manage fire and the exposed. Emergency ventilation is a significant contributor to achieving fire safety in a tunnel trainway and enclosed station during a fire condition. *NFPA 130* recognizes that ventilation system reliability and operability are essential and require a reliability analysis of the electrical, mechanical, and supervisory control systems. Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow must be designed to operate at the fan inlet airflow hot temperature condition of not less than 302 degrees fare height for a minimum of one hour, but not less than the required safe egress time. Some subway ventilation fans operate constantly to prevent accumulation of explosive gas. In the event of a gas alarm, the ROC will activate pre-programmed emergency fans to create significantly more air movement, thereby, lowering concentrations of the gas to a safe level.

The Metro Red Line/Purple Line has one of the technologically advanced and diverse fire life safety systems and facilities in the country. The diversity of the fire life and safety features provides first responders with a familiarity training environment that boosts their implicit learning and resilience (Abujelala et al., 2021). The integration of advanced digital technologies for early fire warning and emergency management augments responders' familiarity training ultimately giving them a better insight into the line's susceptibility to fire accidents and the optimal evacuation strategies for each incidence. The thoroughness of line fire safety measures and integration of technologies allows responders to have a three-dimension familiarity training which is impossible to achieve in older metro subway lines due to shortage of immersive experiences. Based on the observations made by Horn et al. (2019) The subway environment created by the integration of the new fire safety and evacuation tools allows the familiar training to be simulated in a thermal-neutral environment. Training responders in simulated visual atmospheres and live-fire drills allows responders to enhance their physical fitness, stress reactivity, psychological strength, and critical thinking which improves their occupational performance.

13. Conclusion

Fires, derailments, physical rescues and other types of emergencies in the *metro rail* subway systems present a significant challenge to first responders. The type and severity of an incident could range from smoke on a train with no casualties, to a crash and derailment with multiple victims. Due to the significant depths of some areas of the subway system as well as issues with access, communications and ventilation, responders must have familiarity with fire/life safety features and their functions and engage in a coordinated response to incidents occurring in stations or tunnels to reduce loss of life.

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Biography

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