Cross-passageways vs. Emergency Exit Stairways in Rail Tunnels

Justin Edenbaum
Parsons Brinckerhoff
Toronto

Sue Cox
Parsons
Toronto

Gary English
City of Seattle Fire Department
Seattle

ABSTRACT

NFPA 130 provides two egress options for enclosed trainways of transit and passenger rail systems. Tunnels longer than 762 meters require 1) emergency exit stairways or 2) cross-passageways. There is a perception in the industry that emergency exit stairways are safer. Some authorities having jurisdiction (such as local fire departments) reject the cross-passageway option from replacing a stairway.

The paper compares the two exiting geometries. Factors considered are egress of passengers, firefighter response, and cost of installation. This paper helps designers, owners, and authorities make informed decisions based on a comparative analysis.

INTRODUCTION

The fire life safety standard for transit systems in North America is NFPA 130, "Standard for Fixed Guideway Transit and Passenger Rail Systems" (Ref. 1). Section 6.3 of the standard requires exits for train tunnels longer than 762 meters. Despite many efforts, the source of this length is unknown (Ref. 2).

In lieu of emergency exit stairways (stairways) every 762 meters or less, cross-passages can be spaced at 244 m or less. This spacing is approximately one third the 762 meters spacing required for stairways. "The 244 meter devolved from the MARTA (Atlanta) Subway project. It was calculated distance people could walk downstream of a train fire site before flashover occurred and made the downstream environment untenable." (Ref. 2). An additional description is in Ref. 3 and 4.

Even with the shorter spacing, some individuals perceive cross-passageways as a less desirable exiting geometry. In one particular instance, an experienced safety engineer insisted NFPA 130 only allows stairways for egress. Cross-passageways could only be used in lieu of exits when tunnels are underneath water. Only the chairman of the NFPA 130 could correct this individual's misperception; cross-passages have been a valid option since the inception of NFPA 130 in 1983. Appendix A lists North American systems with cross-passageways instead of stairways for tunnels underneath dry land.

This paper objectively compares cross-passageways with stairways to help designers, owners, and authorities make informed decisions. The paper includes a sample emergency scenario to provide a detailed comparison of egress and reconnaissance. A general comparison of other factors is also presented.

EMERGENCY SCENARIOS ASSUMPTIONS

Sample System Configuration

The sample system complies with NFPA 130 and is typical of a heavy- or main-line rail passenger system. Train data is in Table 1.

Table 1: Sample Train Properties

Train length	156 meters
Car length	26 meters
Car width	3048 mm
Number of cars	5
Number of cars downstream of fire	2.5
Number of doors per car, per side	3
Door openings (each side)	3 x 1500 mm
Number of passengers per car	200

The twin bored tunnels have a third-rail and raised walkway, see Figure 1.

The longitudinal tunnel ventilation system supplies sufficient airflow to the fire site to prevent backlayering. The paper describes the airflow patterns for each emergency scenario. The tunnel ventilation system provides a tenable egress route for passengers in the upstream environment, stairways, adjacent tunnels, or adjacent stations during a tunnel fire.

Tunnel ventilation fan plants are located at each end of the stations to provide longitudinal airflow in the tunnel. This layout is typical layout for most new systems.

There is no fire suppression system onboard the train.

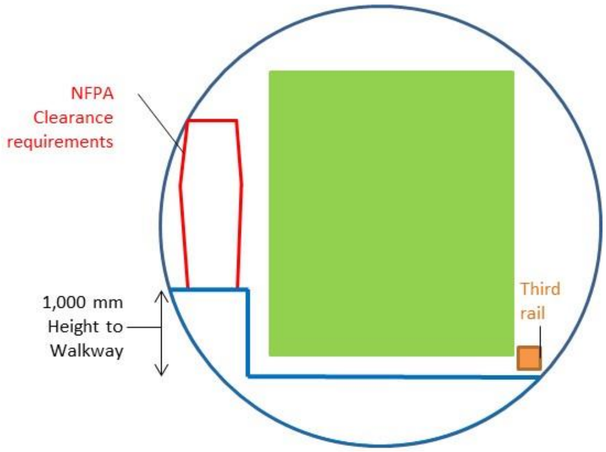

Figure 1: Sample Cross-Section

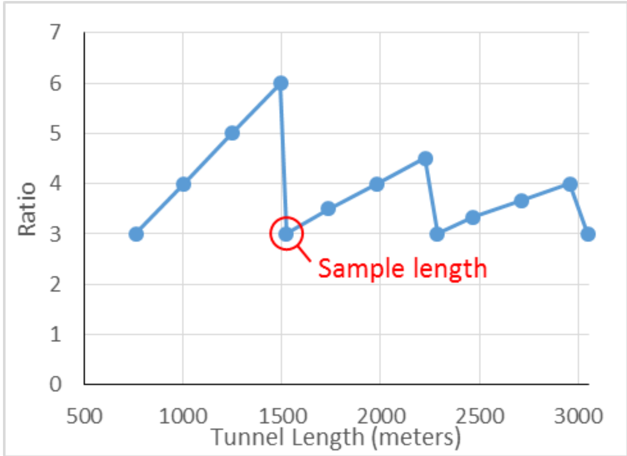

Figure 2: Ratio of Cross-passageways to Stairways vs. Tunnel Length

The assumed tunnel length of 1,600 meters demonstrates a typical case with all factors considered, see Figure 3. This length requires two stairways, assumed to be evenly spaced at 533 meters. Even if the fire disables one stairway, the other stairway can still be evaluated.

The assumed tunnel requires six cross-passages, assumed to be evenly spaced at 229 meters.

Other lengths from 1,200 to 3,000 meters were considered. The length 1,600 meters has the lowest possible ratio of 3 cross-passages to 1 stairway. This ratio is the most common value, see Figure 2. The maximum ratio of 6 cross-passageways to 1 stairway occurs for a tunnel length of approximately 1,500 meters. The next highest ratios are 5.0 and 4.5 cross-passageways to 1 stairway for a tunnel length of approximately 1,250 and 2,200 meters.

Tunnels longer than 3,000 meters were not considered because the extraordinary distance might require different firefighting procedures. The travel time for fire fighters to arrive at the incident site in these long tunnels might require additional considerations, such as rescue trains or powered emergency tunnel evacuation carts.

Fire Scenario

The worst location for a train fire is in the middle of the train (car number 3 of 5) because most passengers are trapped downstream of the fire. The fire occurs underneath the heavy-rail train and disables the train inside of the tunnel.

When the tunnel ventilation system is activated for this fire scenario, half of the train occupants are in a smoky environment downstream of the fire. The train occupants upstream are in a tenable environment.

Two train locations are considered. The first fire occurs on a train located one third of the length of the tunnel between the two stations, see Figure 3. As a conservative but reasonable approach, the fire aligns with and disables the nearest stairway or cross-passageway.

A second fire location is a train in the middle of the tunnel (at 800 meters from either station).

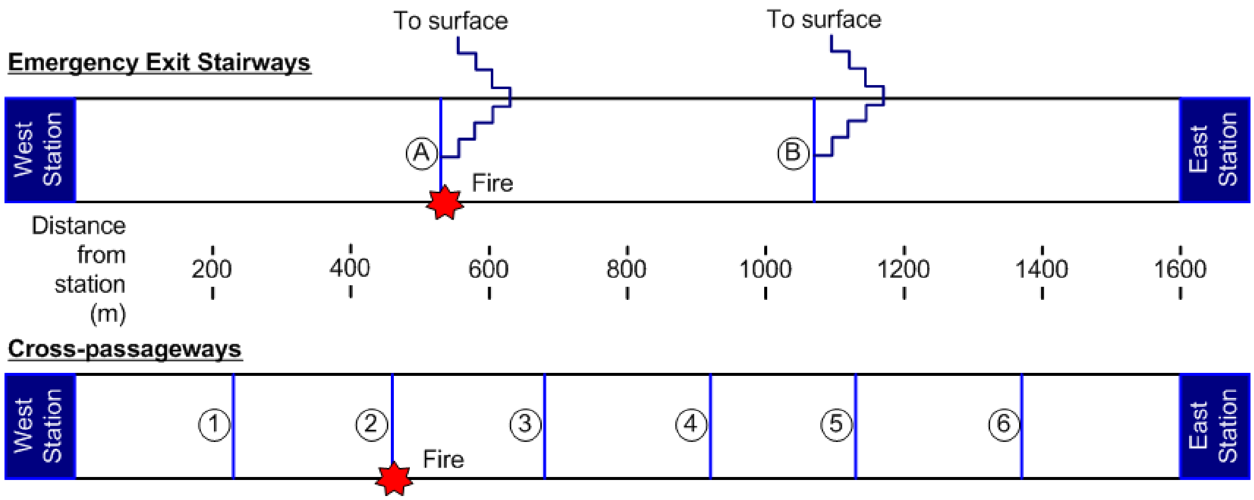

Figure 3: Emergency Scenario with Incident Train at 1/3 the Length of the Tunnel

Both scenarios assume only one train in the incident tunnel, the tunnel where the fire occurs. The non-incident tunnel is the parallel tunnel without a fire.

Egress Assumptions

The assumed egress capacity, egress travel speeds, and calculation are in Appendix B.

The paper focuses on the egress of 500 passengers downstream of the fire, in a smoky environment. The 500 passengers upstream, in a tenable environment, are not considered. These passengers do not obstruct the egress of downstream passengers, rescue efforts, or suppression efforts.

Most passengers self-evacuate. Passengers cannot use the closest stairway or cross-passageway because of its proximity to the fire. The downstream passengers use the stairway or cross-passageways further down the tunnel as it is not safe to move over the fire, therefore evacuation times are longer.

Egress capacities and travel speeds are from NFPA 130, Section 5, as defined for station egress. The capacity and travel speeds are calibrated to the results of the Simulex computer simulations performed in Ref. 3.

The most constricted egress capacity, known as the choke point, occurs where passengers pass the end of the train, see Figure 4. As passengers move past the end of the train, they become aware of the drop from the edge of the walkway to the rail below. The fear of falling slows passengers and reduces the egress capacity by about 20 to 25%. This value is representative for a typical bored tunnel based on the effective widths calculated in Ref. 3, Table 2.

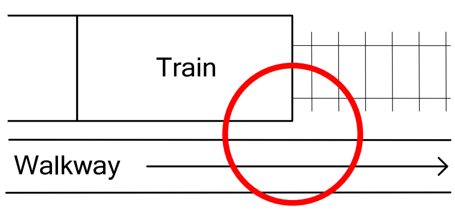

Figure 4: Egress Choke Point on Walkway after Train

The egress capacity of the choke point on the walkway is equal to the egress capacity of the stairway. Therefore, the stairway is not a choke point for the system.

The NFPA 130 compliant cross-passageway is not a choke point because the egress capacity (of the minimum width of 1,120 mm) is greater than the walkway egress capacity. The time to turn and enter the stairway or cross-passageway is neglected to simplify the calculation.

Firefighter movements counter to downstream passengers are not considered in the egress calculations. This movement can impede egress and extend exiting times.

Reconnaissance Assumptions

The paper compares the initial reconnaissance of firefighters for the two different geometries. The goal of reconnaissance is to quickly gather information about the situation. Only after reconnaissance can rescue and suppression be properly planned and executed. Rescue efforts are examined in the comparison section.

To simplify the comparison, the response time the first surface element (station or stairway) is the same. The major differences in reconnaissance time is then due to the internal system geometry.

Prior to arriving at surface elements, firefighters are given the following information:

1. Tunnel with incident train
2. Location of incident train, within a train length
3. Approximate fire location onboard the train
4. Ventilation direction
5. Surface access points upstream and downstream of the fire.

The initial response includes at least two teams, at two different surface access points. For stairways, Team 1 responds to the closest or upstream surface access point. Team 2 responds to the closest downstream surface access point.

For cross-passageways, teams are sent to both station, at each end of the incident tunnel. For all sub-scenarios, the assumption is Team 1 arrives the quickest at the West Station, with Team 2 arriving second at the East Station.

The team arriving upstream of the fire moves in the incident tunnel, in the tenable egress path, to access the fire site.

The downstream team moves closer to the fire site from the tenable, non-incident tunnel. The parallel, incident tunnel can then be accessed from cross-passageways. This team coordinates with the upstream team prior to entering the incident tunnel.

For all cases, no carts or rescue trains are considered to simplify the discussion.

EGRESS AND RECONNESSANCE

Two fire locations are analyzed. The first fire location at one third of the length of tunnel is subdivided into four scenarios, see Table 2. These scenarios cover both system geometries (stairways and cross-passageways) and both ventilation directions (east or west).

Stairways – Fire Location 1

The stairways connect to a passageway between both tunnels and rises to the surface. The stairway next to the fire (Stairway A in Figure 3) is not useable.

SE: Stairway, Ventilation towards East

The tunnel ventilation system provides airflow towards the east, creating a smoky environment east of the fire. The assumed airflow pattern prevents contaminated air from entering the stairway, see Figure 5.

Table 2: Exiting Times

Fire located at 1/3 the length of the tunnel		**Exiting Time (Minutes)**
SE	Stairway, ventilation and downstream towards the east	20
SW	Stairway, ventilation and downstream towards the west	20
CE	Cross-passageways, ventilation and downstream towards the east	12
CW	Cross-passageways, ventilation and downstream towards the west	12
Fire located at 1/2 the length of the tunnel		
Stairway		14
Cross-passageway		9

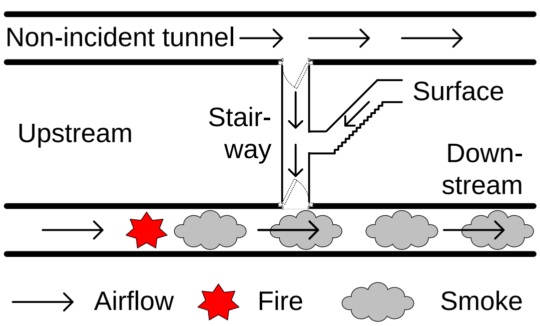

Figure 5: Airflow Prevents Smoke from Entering Stairway

Airflow moves down from the surface connection of the stairway, towards the incident tunnel, and then towards the exhausting tunnel ventilation system. The pressure differential is driven by the tunnel ventilation system and the pressure rise over the fire site.

This airflow pattern has been observed on many different projects. A ventilation analysis needs to verify this flow pattern.

All downstream passengers who can self-rescue reach a tenable environment in 20 minutes. The tenable environment is the bottom of the stairway (Stairway B), 470 meters from the end of the train. The 500 evacuees must ascend the stairway to create room for the "last person" to enter the stairwell

For reconnaissance, Team 1 arrives at the incident stairway (Stairway A) and descends to the tunnel. If the door from tunnel to stairway is not blocked by the fire or derailed train, firefighters can quickly arrive at the fire site. If the door is inaccessible, Team 1 communicates with Incident Command to inform them of Team 1 inability to access and to verify Team 2 has begun access from downstream location.

Prior to communication, Team 2 arrives at the downstream stairway and prepares to enter the tunnel. When descending, firefighters move counter to downstream passengers ascending from the tunnel. This conflict could delay firefighters.

If Team 2 enters the tunnel, they are in a smoke filled environment, 533 meters away from the fire site. No intermediate access points are available.

A third reconnaissance option is for a Team 3 to be stationed upstream at the West station. Emergency responders are needed at this location to handle the passengers evacuating in the upstream environment. Team 3 could approach the fire from the upstream environment and travel 533 meters in the tenable egress path to the fire location. The Incident Commander will determine reconnaissance tactics.

SW: Stairway, Ventilation towards West

The tunnel ventilation system provides airflow towards the west, creating a smoky environment west of the fire. The downstream contaminated air is exhausted through the tunnel ventilation system at the end of the west station, before reaching the platform, see Figure 6. This airflow pattern creates a tenable environment on the platform. Even if some smoke moves into the west station platform, the smoke is diluted to a tenable level.

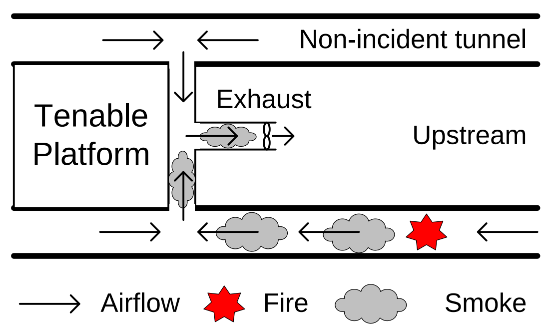

Figure 6: Airflow Creates a Tenable Platform

All downstream passengers who can self-rescue reach a tenable environment at 20 minutes. The tenable environment of the platform is 470 meters from the end of the train.

For reconnaissance, Team 1's arrival and assessment is the same as the previous sub-scenario, SE.

Team 2 arrives at the West station, located downstream, and descends to the tenable environment on the platform (see Figure 6). If Team 2 enters the tunnel, they are in a smoke filled environment that is 533 meters away from the fire site.

A third option is for a third team to arrive at the next Stairway located upstream. Emergency responders are needed to handle the passengers evacuating in the upstream environment.

Cross-passageways – Fire Location 1

The tunnel ventilation system creates a tenable environment upstream of the fire in the incident tunnel and in the parallel, non-incident tunnel. The pressure differential prevents smoke downstream of the fire from entering an open cross-passageway, see Figure 7. The pressure differential is driven by the tunnel ventilation system and the pressure rise over the fire site.

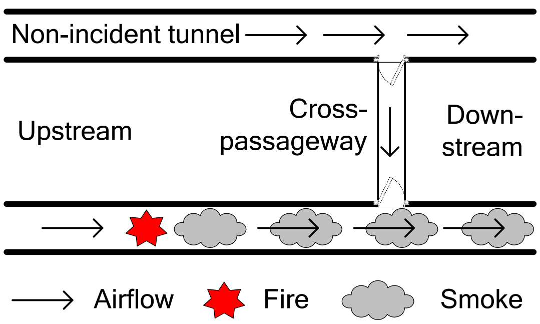

Figure 7: Airflow Prevents Smoke from Entering Cross-passageway

Same as the stairway scenarios, this airflow pattern has been observed on many different projects. A ventilation analysis needs to verify this flow pattern.

CE: Cross-passageways, Ventilation towards East

The tunnel ventilation system moves air towards the east, creating a downstream environment east of the fire, in the incident tunnel.

All downstream passengers who can self-rescue reach a tenable environment at 12 minutes. The tenable environment is the cross-passageway 160 meters from the end of the train. After the cross-passageway, passengers egress through the non-incident tunnel to the upstream or downstream station.

For reconnaissance, Team 1 arrives first at the West Station, located 460 meters upstream of the fire. They move towards the fire in the tenable egress path of the incident tunnel. Eventually, they will encounter passengers escaping on the walkway. While this helps to gather firsthand information about the fire, unfortunately firefighters will probably have to walk on track level to bypass evacuees on the narrow walkway. The track level can present trip hazards. This slows their forward movement.

Team 2 arrives at the East Station, after Team 1's arrival at the West Station. The East Station is located 1,140 meters downstream of the fire. Team 2 starts moving in the non-incident tunnel to be closer to cross-passageways downstream fire. Team 2 may also need to walk on track level.

Team 2 can coordinate with Team 1 via Incident Command to determine which downstream cross-passageway to access the incident tunnel. With the cross-passageway closest to the fire blocked (cross-passageway 2), Team 2 needs accurate information to enter the downstream environment at the cross-passageway 230 meters from the fire site (cross-passageway 3).

CW: Cross-passageways, Ventilation towards West

The egress of sub-scenario CW is symmetrical to CE (Cross-passageways, Ventilation towards East). Therefore, all downstream passengers who can self-rescue reach a tenable environment at 12 minutes.

For reconnaissance, Team 1 arrives first at the West Station, located 460 meters downstream of the fire. The Team starts to walk the non-incident tunnel to get closer to the fire site. At this time, they do not know which cross-passageway way to enter (number 1 or 2).

Team 2 arrives at the East Station, which is 1,140 meters upstream of the fire site. This is a long distance to travel.

During the early stages of reconnaissance, both Team 1 and Team 2 may not be aware that the cross-passageway next to the fire is blocked. Perhaps escaping passengers would be able to describe the situation.

If Team 1 attempts to access the incident tunnel from the inaccessible cross-passageway (number 2), time is lost when they are forced to move back towards the next cross-passageway downstream (number 1).

In the absence of additional information, Team 1 should access the downstream environment from a cross-passageway that is at least a train length downstream of the estimated fire location. This assures they don't waste time at a blocked cross-passageway. In this scenario, Team 1 accesses the incident tunnel from cross-passageway 1, which is 230 meters downstream of the fire.

Middle of Tunnel Scenario – Fire Location 2

If a fire occurs in the middle of the tunnel (800 meters), in the middle of the train, the egress towards the east or west are symmetrical for both geometries (stairways and cross-passageways). The reconnaissance scenario is discussed with ventilation towards the east.

Middle Fire with Stairway

All downstream passengers who can self-rescue reach a point of safety after 14 minutes. The point of safety is the stairway 200 meters away from the end of the train.

For reconnaissance, Team 1 arrives at the upstream stairway (Stairway A) and descends to the tunnel. While descending, fire fighters may conflict with upstream passengers ascending from the tunnel. In the tunnel, Team 1 is 270 meters upstream of the fire.

Team 2 arrives at the downstream stairway and prepares to enter the incident tunnel (similar to SE). They are located 270 meters downstream of the fire.

With this reconnaissance, neither of the first two teams are located at a station.

Middle Fire with cross-passageways

All downstream passengers who can self-rescue reach a tenable environment at 9 minutes. The point of safety is a cross-passageway approximately 50 meters away from the end of the train. This distance is closer than cross-passageways in sub-scenarios CW and CE.

For reconnaissance, Team 1 arrives first at the West Station, located 800 meters upstream of the fire. Fire fighters can start to access the incident tunnel from the upstream environment.

Team 2 at the East Station moves 680 meters in the non-incident tunnel to the cross-passageway (number 4), just downstream of the fire. After coordinating with Team 1, Team 2 can enter the incident tunnel at the cross-passageway 120 meters downstream of the fire.

COMPARSISON

General statements compare stairway and cross-passageway systems. All statements apply to the fire locations above and most fire locations.

Egress

Systems with cross-passages enable passengers to escape a smoky environment faster than systems with stairways. For the scenarios presented, those able to self-rescue exit the downstream, smoky environment of the cross-passageway geometry 35% shorter than the stairway geometry.

Egress times of cross-passage geometries can be comparatively shorter for other tunnel lengths. Egress times are faster when exits are closer. As shown in Figure 2, cross-passageways provide 3 to 6 times more exits than stairways. The probability is higher that the downstream exit from a fire is much closer for a cross-passageway geometry than a stairway geometry.

Reconnaissance

Systems with stairways enable firefighters to reach fire locations faster than systems with cross-passageways. Stairways enable firefighters to have shorter travel distances from the surface access point to the fire locations.

On the other hand, the stairway geometry usually requires firefighters to walk in a smoky, downstream tunnel environment for double the distances required in cross-passageway geometry. Using most of the firefighter tank air simply walking in the smoke to the incident and back out over a longer distance can significantly limit the amount of time available to perform reconnaissance, suppression, and rescue efforts.

Suppression

Stairways geometry is likely quicker for fire suppression because reconnaissance is faster and firefighters can access the fire location faster.

Rescue

There are challenges moving those unable to self-rescue from the downstream environment of both geometries. For stairways, firefighters are probably going to reach those unable to self-rescue faster than cross-passageways. On the other hand, firefighters and the rescued need to travel longer distances in a smoky tunnel. Upon arrival at the stairways, rescued passengers need to be carried up stairways which might be narrow and therefore difficult.

For cross-passageways, those unable to self-rescue can be brought to a tenable environment faster. On the other hand, they cannot immediately be brought to the surface. They need to be transported to a station. From the station, moving those unable to self-rescue to the surface is easier at stations than using the narrow stairways connected to the tunnel.

Capital costs

Designers can compare costs of the two different exit geometries for each project. Costs vary greatly depending on the local environment. Cross-passageways are a cheaper exiting geometry when capitol cost for each cross-passageways are 1/3 or less of each stairway. Keep in mind the cost of a stairway may include the purchase of surface elements.

A recent project estimated an emergency exit stairway and cross-passageways cost of $15 and $1 million USD each. Using these costs and the sample tunnel length of 1,600 meters, capital costs for stairways and cross-passageways are $30 million and $6 million. The cross-passageway geometry cost is 20% of the stairway cost. Even for the worst cross-passageway to exit stairway ratio of 6 to 1 (for a tunnel length of approximately 1,500 meters), cross-passages costs are 40% of the stairway costs.

CONCULSION

There is no definitive answer on which geometry is safer during a tunnel fire. Cross-passageways provide quicker egress times for those unable to self-rescue. On the other hand, stairway geometry typically allows faster reconnaissance and suppression.

For rescue, each geometry has their own advantages and disadvantages. Different procedures are required for each.

For capital costs, cross-passageways are typically more cost effective. This is true when capital cost for each cross-passageways are 1/3 or less of each stairway.

The perception that cross-passageways are a less desirable exiting geometry is unfounded. In fact, this exiting geometry can dramatically reduce capital costs. Additionally, this geometry provides shorter egress times for those unable to self-rescue, more access points and exits to the incident tunnel, and shorter travel distance in smoky tunnels for firefighters.

ACKNOWLEDGEMENTS

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Appendix A: North American Systems with Cross-passageways instead of Stairways for Tunnels Underneath Dry land

Agency	Project	Location	Description of setup
MARTA	Entire system	Atlanta, GA	Cross-passages spacing is approximately 240 meters.
BART	San Francisco Airport Extension	San Francisco, CA	8 km between Colma and San Bruno. 2 stations. Cross-passages spacing is approximately 90 meters.
BART	San Francisco Airport Extension	Millbrae, CA	1.6 km. 0 stations. Cross-passages spacing is approximately 90 meters
BART	Warm Springs Extension	Fremont, CA	1.6 km. 0 stations. Cross-passages spacing is approximately 90 meters
MTA	Number 7 extension	New York City	Maximum length of tunnel is 1.2 km. Cross passages spacing is approximately 180 meters.
LA Metro	Purple Line West Side Extension	Los Angeles	Cross-passageway spacing is approximately 230 meters.
TriMet	LRT	Portland	5 KM tunnel at maximum depth of 50m from the surface. One station is located approximately 3,100 m from one portal. Cross-passages spacing is approximately 240 meters

Table 1B: Egress Rates

Description	Variable	Value	Unit	Source
Flat surfaces				
Maximum means of egress **travel speed** along platform, corridors, and ramps	Fts	37.7	m/min	NFPA 130, 5.3.4.4
Maximum means of **egress capacity** of platforms, corridors, and ramps	Fec	0.082	p/mm-min	NFPA 130, 5.3.4.3
The trainway's widest **unobstructed clear width** requirement for the means of egress.	MinW	760	mm	NFPA 130, 6.3.2.1
Capacity of walkway (Assumed width of 760 mm)	Cwp	62.2	p/min	Fec * 760 mm
Stairs				
Egress capacity	Sec	0.056	p/mm-min	NFPA 130, 5.3.5.3 (1)
Travel speed, vertical component of travel speed	Sts	14.6	m/min	NFPA 130, 5.3.5.3 (2)
Minimum stair width	MinSW	1120	mm	NFPA 130, 6.3.2.3
Capacity of minimum stair width	CS	62.2	p/min	MinSW * SEC
Passengers				
Number of passengers downstream	Pass	500	Passengers	= 2.5 Cars downstream * 200 passengers per car

EE: Exits, Ventilation and downstream towards the east				
#	**Event**	**Value**	**Unit**	**Source**
1	Train length, downstream of fire and stairway	65	m	= 2.5 * Car length
2	Distance between exits	533	m	= 1,600 m / 3 for two exits
3	Distance from end of train to stairway	468	m	= #2 - #1
4	Time for people to move past end of train	8.0	min	= Number of passengers downstream / walkway capacity (Cwp)
5	Walking time for last person to stairway	12.4	min	= #3 / Flat travel speed (Fts)
6	Total egress time to bottom of stairway	20.4	min	= #4 + #5
7	Vertical distance of stairs	15	m	Assumed
8	Time from bottom to top stair	1.03	min	#7 / Stair travel speed (Sts)
9	Time to surface (point of safety)	21.47		#6 + #8

EW: Exits, Ventilation and downstream towards the West

#	Event	Value	Unit	Source
1	Train length, downstream of fire and cross-passage	65	m	= 2.5 * Car length
2	Distance between exits	533	m	= 1,600 m / 3 for two exits
3	Distance from end of train to station downstream	468	m	= #2 - #1
4	Time for people to move past end of train	8.0	min	= Number of passengers downstream / walkway capacity (Cwp)
5	Walking time for last person to station downstream	12.4	min	#3 / Flat travel speed (Fts)
6	Total egress time to station downstream	20.4	min	#4 + #5

CE & CW: Cross-passages, Ventilation and downstream towards the east or west

#	Event	Value	Unit	Source
1	Train length, downstream of fire and cross-passage	65	m	= 2.5 * Car length
2	Distance between cross-passages	229	m	= 1,600 m / 7 for six cross passages
3	Distance from end of train to cross-passageway	164	m	= #2 - #1
4	Time for people to move past end of train	8.0	min	= Number of passengers downstream / walkway capacity (Cwp)
5	Walking time for last person to cross-passageway	4.4	min	= #3 / Flat travel speed (Fts)
6	Total egress time to cross-passage	12.4	min	= #4 + #5

Middle Fire with Stairway

#	Event	Value	Unit	Source
1	Train length, downstream of fire	65	m	= 2.5 * Car length
2	Distance between exits	533	m	= 1,600 m / 3 for two exits
3	Distance from end of train to stairway	201.5	m	= #2/2 - #1
4	Time for people to move past end of train	8.0	min	= Number of passengers downstream / walkway capacity (Cwp)
5	Walking time for last person to stairway	5.3	min	= #3 / Flat travel speed (Fts)
6	Total egress time to bottom of stairway	13.4	min	= #4 + #5
7	Vertical distance of stairs	15	m	Assumed
8	Time from bottom to top stair	1.03	min	= #7 / Stair travel speed (Sts)
9	Time to surface (point of safety)	14.41		= #6 + #8

Middle Fire with cross-passagewayways

#	Event	Value	Unit	Source
1	Train length, downstream of fire	65	m	= 2.5 * Car length
2	Distance between cross-passageways	229	m	= 1,600 m / 7 for six cross passages
3	Distance from end of train to cross-passageway	49.5	m	= #2/2 - #1
4	Time for people to move past end of train	8.0	min	= Number of passengers downstream / walkway capacity (Cwp)
5	Walking time for last person to cross-passageway	1.3	min	= #3 / Flat travel speed (Fts)
6	Total egress time to cross-passageway	9.3	min	= #4 + #5