Platform Edge Detection and Protection Effects on Platform-Train Interface Safety

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ABSTRACT

The purpose of this study is to provide background information and examples of best practices relating to platform-train-interface (PTI) safety. This manuscript was adapted from a literature review that was undertaken as part of the Transit Cooperative Research Program (TCRP) project A–40 that aims to improve platform safety for rail modes of public transportation. The findings come from an extensive literature review, transit operator safety data, input from two workshops, and interviews with various stakeholders. Specifically, information was gathered from transit operators, station designers, station builders, car builders, and accessibility equipment manufacturers. The background research has shown that platform safety is primarily affected by technical factors, operational aspects, and passenger characteristics. This paper identifies possible issues and best practices for the technical design aspects of platform edge safety. It was determined that certain factors are universal between modes and can be grouped together. However, the research suggests that each mode has many factors that should be considered separately when determining potential mitigation strategies. The second part of this paper considers each mode separately.
INTRODUCTION TO PLATFORM-TRAIN-INTERFACE SAFETY PROBLEMS

Many transit agencies and researchers recognize that the platform-train-interface (PTI) accidents are an important safety concern, however there has been relatively little research in this area. Incidents that involve the gap between the platform and train are not necessarily only dependent on the gap size. In fact, literature review suggests that there may be many other contributing factors that could impact boarding and alighting safety. Various studies from around the world have considered portions of this overarching problem of gap safety in various rail transit modes. These documents have been reviewed and the pertinent information was extracted to insure that this study could effectively address issues surrounding the platform-train-interface. This paper is based on research that is currently being undertaken as part of the Transit Cooperative Research Program (TCRP) A-40 project. The objective of this research is to develop a manual for practitioners to improve safety at rail public transportation platform/train and platform/guideway and roadway interfaces. The research should assist transit agencies to prevent and minimize incidents and improve safety. This research focuses on rail transit but may include Bus Rapid Transit systems where car/bus floors are level (or near level) with their platform. This paper focuses on the platform train interface (PTI).

SIGNIFICANT ISSUES

Geometry and Size

One of the major design aspects that can affect safety at the platform-train-interface is the gap size influenced by the track infrastructure. Different modes of rail transit often encounter different issues relating to the track on which they operate. Rail transit operations are generally divided into two different categories, exclusive track operations and shared track operations. Shared track operations include sharing the track with freight trains as well as other rail transit modes in certain instances. Commuter rail systems quite often share track with freight and thus the station platforms need to be set back further from the track to comply with freight car clearances. Light rail and street car operations sometimes share platforms with each other and/or buses. In these operations platforms must be designed to accommodate level boarding for various modes. Conversely, exclusive track operations involve a guideway that is reserved for a specific type of rail transit. For example, heavy rail transit operations such as those reported in the studies involving Tokyo and Bangkok generally only have to consider horizontal gaps resulting from platforms that are on curves.

The use of a gauntlet track, is one solution to solve mixed operations problems with regards to horizontal gap distances. One example of this method comes from the Westside Express Service (WES) commuter train operated by TRIMET in Portland, Oregon (see Figure 1). The 14.7 mile long corridor has five stations and operates on shared track with a regional freight railroad. The Oregon Department of Transportation (ODOT) required a clearance distance of seven feet and three inches (7’ 3”) from centerline of the track to the edge of the station platform. During the project development phase it was determined that the car widths for the proposed diesel multiple unit trains were only 10 feet and 10 inches wide (5’ 10” from centerline to edge of vehicle). Thus, in order to comply with the Americans with Disabilities Act (ADA) regulations of a maximum three inch (3”) horizontal gap, something had to be done. Various suggestions such as mini-high platforms, motorized platform extensions, manual platform extensions, and gauntlet tracks were considered. In the end the gauntlet track was selected as the preferred alternative. The gauntlet track consists of two switches roughly 466 feet apart (point of switch
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to point of switch) for a platform length of 146 feet. These switches move the commuter trains approximately one foot and 8 inches closer to the platform while allowing freight trains to remain the legal distance. With this shift, the horizontal gap is reduced from one foot and 10 inches down to two inches, respectively. This gap is fully compliant with the ADA regulations. TRIMET estimated that an installation of a gauntlet track for a platform length of 146 would be about $650,000 including materials, signal work, and installation costs. Based on the success observed with WES in Portland, more applications of gauntlet tracks could be suggested for similar areas with mixed rail operations (1). A report published by the Federal Railroad Administration (FRA) entitled Managing Gap Safety also suggests gauntlet tracks as a potential solution to the excessive gap problem (2). It should be noted that New Jersey Transit also currently has a gauntlet track in operation at Union Station on the Raritan Valley Line(3).

FIGURE 1 Gauntlet Track at Station in Portland, OR (Ken Kirse).

Another reason often cited for the presence of excessive gaps are stations in curved track sections. Numerous studies mention the problems related to curved station platforms located on curved track sections and the challenges that come with them. A document outlining the origins of “Mind the Gap” offers some information on why these curved platforms can cause significant problems. As stated by that paper and a study from Tokyo University of Science, there are two primary classifications for stations in curves. In the first case, a station is located on the outside of a curve (concave). This allows the ends of the cars to be near to the platform but the center doors could have a significant gap present. The opposite is true for the second case when the station is located on the inside of a curve (convex). In this scenario the middle sections of the cars are near to the platform and ends are further away. The severity of the gap depends significantly on the rail car layout and the degree of curve in which the station is located(4). The New Jersey Transit study presents a similar conclusion in regards to stations in curves(5). The model presented by the researchers from Tokyo University of Science also takes curvature into account. According to their study, stations that are in concave curves are slightly better in terms of gap safety than convex curves. They do not offer much support as to why they made this choice however (6).

Two additional significant factors in the study from Japan were the overall area of the platform and the length of narrow or obstructed sections on the platform. According to the results, as the area of the platform increased so did the overall safety of the platform. Conversely, as the length of the narrow sections of the platform increased the overall safety at the platform decreased. These conclusions seem to make sense from the perspective of avoiding overcrowding issues. In general, it is understood that larger platforms with more standing area are safer than those that are smaller. Additionally, island platforms and those with curves were considered to be more dangerous than single sided platforms and those that were straight (6).

As previously mentioned, the platform shape could potentially have an effect on safety. Unfortunately it seems that there is not a general consensus of whether island platforms or side platforms are truly safer. Some advantages that are listed for island platforms include using less right-of-way, ease of transfer between tracks for both passengers and trains, shared facilities, and potentially fewer station attendants needed. However, the island platforms can also have issues such as overcrowding when two trains are present on either side, crossing passenger flows, and overcrowding on stairs and escalators. Conversely, the side platforms can offer more standing area and eliminate the problem of crossing passenger flows. There are many factors that contribute to the selection and design of the platform. These factors are specific to the location and are generally determined by the geometric characteristics, right-
way availability, station location, passenger load, and transferability to other modes or trains. Further research into platform type and its’ relation to safety could be very useful (7).

**Platform Clutter**

The obstructions caused by amenities and general platform clutter influence the amount of “clear space” on the platform, and therefore consideration should be given to the location and density of obstacles. Examples of these include seats, station support columns, informational boards, stairs, elevators, and escalators. While many of these objects are necessary on a platform, the placement of these can be crucial to platform safety. Too many objects on the platform reduce the overall area and fixed obstructions such as stairs and escalators cause there to be narrow portions on the platform. These problems lead to overcrowding and involve passengers standing too close to the edge of the platform. Additionally, special care should be taken when temporary construction or maintenance sites are set up to avoid creating potentially dangerous narrow platform sections (7).

**Between Car Barriers**

One issue that emerged during background research on the platform-train-interface was barriers between cars to prevent track intrusion. This was not the specific focus of the research project, however there is a relationship to overall platform safety. A report published by Reiss details the efforts of the Los Angeles County Metropolitan Transportation Authority (LACMTA) to become ADA compliant with regards to between car barriers (BCBs). The goal of the study was to find a station based protection system that could be universally applied in contrast to a vehicle based solution. One of the largest challenges LACMTA faced was the large variety of vehicles operating on their lines. Currently, there are many different models of light rail vehicles (Gold, Blue, and Green lines) and heavy rail vehicles (Red/Purple Subway Lines) operating on the system. The varying models, ages, and dimensions made it difficult to come up with an on vehicle solution that worked for all models. Thus, after years of design and testing, a solution of platform based hinged bollards was implemented (See Figure 2). The hinges were required by the California Public Utility Commission (CPUC) to allow passengers access to the door if the train did not stop in the proper location. The installation of the bollards even had an unanticipated positive effect for the visually impaired. According to survey responses, the trains stop so reliably that people with low vision can use the bollards to determine where the train doors will be. So not only do they improve safety with regards to reducing the number of accidents of falling between cars, they can also be used as way finding devices for visually impaired passengers (8).

**FIGURE 2 Bollard Between Car Barrier in Los Angeles, CA.**

San Francisco Municipal Transportation Agency (SFMTA) has also worked to develop a between car barrier device for their light rail vehicles. The solution came in the form of three evenly spaced elastic bands that extend from one vehicle to the adjacent vehicle (see Figure 3). The bands contain high tensions springs that allow them to expand up to 13 feet in length when cornering. In addition a black and yellow striped paint scheme has been utilized to bring additional attention to the devices and keep passengers away from the gap between vehicles (9).

**FIGURE 3 Elastic Band Between Car Barriers in San Francisco, CA.**
Safety data collected from several transit agencies and input from the project workshops suggest that between car injuries are indeed a problem. There were numerous cases reported from transit agencies that involved low vision and distracted passengers. This seems to suggest that between car protection should be provided when a gap exists between two cars or vehicles. Solutions to this could come in many forms including the previously discussed bollards that LACMTA has implemented or the elastic bands used in San Francisco. Additional possibilities may include using an alternative car based protection system such as chains or plastic paddles that extend from each car or vehicle. During the TCRP A-40 online webinar that brought together various stakeholders that are concerned with platform-train-interface, it was mentioned that often in Europe the train cars are interconnected and have no space between them. This could be an interesting consideration for transit operators and vehicle builders when they are designing cars for the North American markets (7).

**Edge Warning Lights**

A unique solution that could help to improve safety at the platform-train-interface is known as edge warning lights. The most prominent application of this technique is in the Washington D.C. Metro (See Figure 4). LED lights are imbedded in the edge of the platforms and spaced equally throughout the entire length of each platform. The bulbs burn steady at 50 percent power and flash at 100 percent when a train is either approaching or currently in the station. Initially the lights were installed to alert both hearing-impaired and general riders that a train was approaching and encourage people to step back from the platform edge. The lights were successful in this regard and have been installed throughout the system. In theory the lights can improve safety by notifying passengers that a train is approaching and drawing further attention to the edge of the platform. Additionally, the lights are color coded to reflect which line the train is operating on. For example the red LED lights are present on platforms that are along the Red Line. Amber lights are on the platforms that are in stations on the Green and Yellow Lines (5)

![FIGURE 4 Edge Warning Light Treatment on Washington D.C. Metro.](image)

**Platform Screen Doors (PSD)**

Multiple studies have mentioned platform screen doors (PSD) as a potential method to improve safety at the platform-train-interface. Automated train operations and driverless train operations are also motivations for implementing PSD.

Platform screen door design is largely dependent on location and transit system preference. There are three primary configurations for platform screen doors used around the world. Full height doors have the advantage of being able to contribute to climate control and essentially ensures that no one can enter the guideway until the train is present. In underground stations the full height doors must satisfy fire and life safety standards. Most full height door systems leave a slight gap between the ceiling and wall for ventilation. This option is often less expensive than the full height doors and still prevents people from entering the guideway.

One of the additional benefits of platform screen door installation is climate control and passenger comfort. Underground stations in Singapore have been retrofitted with full height PSDs to help improve safety and to reduce the costs of providing air conditioning on the platforms. The savings from this are significant and passenger comfort has improved immensely since the installation. In grade and
above grade applications doors and half height barriers/doors are more common (See Figure 5). As the name suggests, they only extend up to about chest height depending on the specific system. This configuration represents the most cost effective way to install platform screen doors but does not produce any climate control benefits. Train noise suppression is slight if any but it does allow for ventilation between platform and guideway. One potential problem with half height doors is that a person could still potentially climb up over the wall and enter the guideway (13).

The study produced by New Jersey Institute of Technology lists PSDs as a possible mitigation strategy to improve platform safety (5). Additionally, the report published by Santoso and Mahadthai actually focuses on PSDs effects on platform safety on the Bangkok Mass Transit System (BMTS). According to the findings, accidents that are attributed to the platform-train-interface (PTI) account for about 38 percent of the overall fatality risk and of that risk about 9 percent specifically deal with boarding and alighting incidents. The doors have been proven to improve certain safety aspects surrounding the PTI but that improvement can come at a high cost. When BMTS distributed a survey to passengers asking various questions on platform safety, over 75 percent of the respondents thought the installation of PSDs would improve safety. However, if the installation meant a fare increase of roughly 20 cents in US equivalent dollars, the PSDs lost much of their support. The same trend was observed for increasing the number of conductors on the platform in lieu of door installation. Based on these results it can be concluded that passengers appear to want PSDs for safety reasons but are unwilling to pay more to have them installed. Additionally, one of the initial concerns for the transit agency with regards to installing PSD’s was the loss of platform surface area for passengers to stand and move during boarding and alighting. According to the BMTS study, the presence PSDs do not significantly disturb passenger flows during boarding and alighting and thus do not have a large effect on dwell time or overall capacity (10).

One of the primary concerns that transit agencies may have with regards to PSD implementation could be inoperability. Many agencies operate multiple designs or models of the same mode of vehicle. The differences between these vehicles with relation to the number, location and even style of doors and dimensions causes issues with docking at specific PSD locations. However, as stated by an APTA (American Public Transportation Association) publication on intrusion detection, if PSDs are feasible there can be many advantages. Some of these include faster train approach speeds, reduced noise levels, and reduced heating/cooling costs (11).

An internal case study completed by the Taipei Rapid Transit Corporation also makes some conclusions as a result of previous installations of PSDs on various rail transit lines under their jurisdiction (See Figure 5). Platform screen door installations began in 2005 and have continued periodically since that time. One of the motivations for the installation came from a report on the Paris Subway stating that the number of delays caused by passengers was reduced by 69 percent after the installation of PSDs. However, installation was a slow process in Taipei and it took months to do a single station based on lack of available time to work due to efforts to minimize effects on normal operations. Initially doors that were 1.45 meters tall and 1.8 meters wide were installed. However, as more stations were equipped with PSDs, the heights of the doors have been reduced slightly to 1.4 meters and the width has increased to 2.1 meters to increase visibility and passenger flow. Additionally, the doors are equipped with automatic detection sensors that prevent them from closing on passengers and causing injuries. Recent successes with the PSD’s have encouraged the Taipei Rapid Transit Corporation to continue installing the doors at heavily congested stations. The most recent set of installations at 13 additional stations will be completed in 2014, continuing to improve safety on the overall system (12).
According to an article that was written for a Vancouver, B.C. based news source, there have been approximately 60 track intrusion related deaths since the SkyTrain system opened in 1985. A majority of those deaths have been suicides but at least ten of them were accidental in nature. Implementation of platform screen doors would be a possible solution to these intrusion problems. However, there are possible obstacles that stand in the way of implementation of these doors. One of the major obstacles that exists involves the various types of rolling stock that operate on the various lines. Currently, Mark I and Mark II cars operate on both the Millennium and Expo Lines. Unfortunately the door spacing is not standard between the two vehicle types. Additionally, Mark III vehicles will be introduced in 2016 in conjunction with the opening of the new Evergreen Line. Having three different types of vehicles with varying door spacing would make platform screen door implementation difficult. On the other hand, the Canada Line uses Hyundai Rotem cars that only operate on that line. Thus it may be possible to have platform screen doors at those stations from a rolling stock standpoint. However, high costs of installation and maintenance could stand in the way of the PSD implementation (13).

Delay is generally a big concern for most rail transit agencies when considering the reliability of a given system. It is therefore important to understand the potential effects that installing platform screen doors could have on delay on a rail transit line. The feasibility report regarding installation of platform screen doors prepared for BC Transit contained a delay impact analysis that concluded that the potential delay with the platform screen doors would be less than half of the delay with the current system. One major assumption for this comparison was the assumption that the platform screen doors failed at about the same rate as that of the car doors. Additionally, it was assumed that the intrusion detection systems would be removed and thus no delay would be encountered from those systems. The findings suggest that the PSD’s would reduce delay significantly over the course of an average month (14). Similarly, results from installation of half height PSDs on Hong Kong’s MTR system suggest that service interruptions due to intrusion dropped nearly 70 percent (13).

Platform screen doors will be installed at all of the 21 stations along the future Honolulu Rapid Rail Transit line. The decision to install the doors was supported by both planners and the community at large. This is because the system is both elevated and automated. The half-height doors will be laminated safety glass and will run along the entirety of each platform. As observed by other systems around the world, installing the doors would be significantly cheaper if done during initial construction rather than retrofiting later. Thus the automatic doors will be installed at an estimated cost of about $27 million total for all of the platforms in the 21 stations (15). In automated metro operations, the cost of platform screen doors is offset by the savings in labor over ten years (16).

### Intrusion Detection Technologies

Platform edge and track intrusion detection devices are a relatively new technologies that are under consideration for transit related purposes. The technology for the platform intrusion detection (PID) systems has become more sophisticated and can be far more economical to install and operate as compared to PSDs. However, they do not offer a physical barrier between the edge of platform and track. One example of this technology is in Yong-In, South Korea. A series of light curtains are employed to detect when a person comes within 12 inches of the edge of a platform when no train is present. If detected, an automated public address message is triggered and an alert is sent to the dispatchers at central
control. While this specifically does not address gap problems it could potentially be modified to detect passengers falling into excessive gap areas. One of the potential drawbacks of this technology is implementation of light sensors on curved platforms is difficult (11).

A case study for guideway intrusion detection is derived from SkyTrain operated in the Vancouver, British Columbia. Currently SkyTrain has basic intrusion detection that varies from lasers to metal pressure plates. The main purpose of these detection technologies are to prevent an incoming train from hitting a passenger that is on the tracks. The laser detection systems that are present on the newer lines can detect a passenger that moves too close to the platform edge and issues an audio warning of the potential danger. The second phase of the system involves lasers that can detect an object that has fallen on the track. Once detected, an alert is sent to the central control room and trains cannot enter the station until the foreign object has been cleared.

The original Expo Line still utilizes the pressure plates. This system is present on the tracks at stations and operates similar to the track laser system. If an object puts pressure on the plate it issues an alert to the central control room and does not allow trains to enter that station on that track. The system is very effective. In fact, the sensitivity is so high that a dropped wallet or an aluminum can will set off the alert and stop trains. According to the same article, in May 2010 there were at least 80 service disruptions caused by garbage falling onto the tracks and creating false alarms. While the idea behind this intrusion detection method was sound, the operation has proven to cause many system wide delays (13).

MODE SPECIFIC CHALLENGES

Each specific rail transit mode experiences different problems in relation to platform edge safety. These differences can be due to a variety of factors including differences in guideway design, platform heights, station layout, operating on shared right-of-way, vehicle size, vehicle configuration, and operating speed. Problems related to each rail transit mode should be considered separately when recommending potential solutions to improve safety at the platform train interface (PTI).

Heavy Rapid Rail

Rapid rail transit generally experiences less technical problems than other rail transit modes with regards to PTI safety. This is because rapid rail systems nearly always operate on exclusive track and they do not need to accommodate freight activity or other modes such as buses. One of the major challenges for rapid rail can be attributed to varying vehicle sizes and configurations. Often transit systems incorporate new vehicles into the fleet while continuing to operate the older vehicles. Generally the new vehicles have been updated to improve safety, capacity, and/or comfort and therefore the layout and/or dimensions can vary slightly from the legacy cars. This can be a significant problem if the car width or floor heights change slightly. One example of this problem is encountered in the London Underground which has experienced problems due to the integration of various styles of trains. Trains operating on the Bakerloo line are known as small profile trains and differ in size from the standard profile trains that are present on other parts of the system. In fact, the small profile trains have a floor height that is approximately four and a half inches lower than the standard profile trains. This creates problems when the smaller trains cross over onto the lines where standard trains operate. The platforms on these lines have level boarding for the larger trains but require a step down to board or step up to alight for the smaller trains (17).

Another additional problem with rapid rail transit comes from the legacy systems and in particular those that are underground. Initially these systems were laid out to serve the maximum number
of passengers but often this was often done by sacrificing favorable geometry. Many of the stations are located in curves and present some serious issues with excessive gaps both vertically and horizontally (4).

The FRA manual on Managing Gap Safety lists movable platforms as a possible solution to gap issues. These gap fillers are automatically moved into place when the train comes to a stop. This method can be especially effective on curves where the gap is excessive. Additionally, some railroads have platforms with fold up edges that are moved out of the way when a train is not present at the station. One unusual mitigation effort uses a rubber gap filler that has fingers that extend from platform. This configuration allows some fall protection and can bend if the car comes in contact with the device (2).

One example of a mitigation technique used to reduce the gap for rapid rail is shown in the New York City Subway System. Certain platforms on the system use movable platforms to help eliminate the horizontal gaps. Signs and audio warnings alert passengers to the moving surface and aim to make passengers aware of the movement. Even with these efforts there have reports of people ignoring the warnings and losing their balance during operation. One potential disadvantage of moving platforms is increasing of dwell time. In fact, certain platforms in New York Subway’s 42nd Street Station were built initially with moving platforms to fill gaps. However, the platforms were later secured in place by concrete because of the effect on dwell time at the platforms (7).

Light Rail and Streetcar

The achievement of level boarding is a problem for some modes of rail transit. The design of the new Kansas City Downtown Streetcar system had to solve this challenge. The vehicles that were selected for this new system have ADA accessible doors in the middle section of the train but not at either end. Accordingly, the station platforms have been designed to reflect this feature. The platforms have a 14 inch high level boarding section in the middle that is designed to line up with the two doors to the accessible spaces on the streetcar. The middle portion of the vehicle is configured to allow for maneuverability of wheeled mobility devices by those protected under ADA. At either end of the station, the platform dips down to 7 inches high which requires passengers to step up or down to get on or off the streetcar. One of the primary reasons for this design was to reduce the streetcar stations footprint in the urban environment. According to the design documents, nearly half of the station locations are space constrained by obstacles such as parking, loading zones, and driveways. Providing only the middle two doors for level (accessible) boarding reduces the footprint significantly compared to a traditional platform that has all doors with level boarding. The second reason for this configuration is to allow the existing buses in Kansas City to use the stations. The configuration of the buses will allow for level boarding in the rear and level boarding in the front when the buses kneels. This platform style is also used for the Washington D.C. streetcar (18). Additional streetcar station design guidelines can be found in the Modern Streetcar Vehicle Guidelines manual that is published by APTA (Modern Streetcar Design Guideline). It should be noted that while it is less common, in Seattle the light rail system and buses share platforms (19).

One of the unique characteristics of the street running rail transit modes (light rail and streetcar) is the use of low platforms. This can be a problem because people can easily step up and down from the guideway to the platform. A lower platform reduces the severity of injury if someone were to fall, however the smaller height differential makes it easier for passengers to enter the guideway or in the case of some cities to use the platform edge as a bench. The report detailing intrusion detection technologies by Jonathan Hulse confirms this and goes on to suggest that people would be very willing to enter the
guideway to pick up an object or navigate around crowds. While light rail and street car vehicles generally move slower when they are operating in the street, this passenger behavior is still be considered to be an unnecessary risk (11).

**Commuter Rail**

Commuter rail may experience some of the most severe issues in relation to the platform train interface of all the rail transit modes. The combination of high platforms, various vehicle heights, and shared right-of-way introduces some unique challenges. The most prominent issue from that list is often considered to be operation on shared right-of-way. Sharing track with freight allows commuter systems to utilize existing rail infrastructure without the additional costs of installing track, structures, and signal systems. This also allows for shared maintenance and dispatching which can further reduce the costs to the transit agency. Two primary disadvantages exist with shared track operation. Train delay can be a significant issue but is not the focus of this report. The second problem results from freight car clearance standards. Most commuter railroads tend to follow Plate C standards that is set forth by the Association of American Railroads (AAR). This states that the maximum width of a car cannot exceed ten feet eight inches (10’ 8”). Thus when a station is designed for commuter rail, the platform is set back to ensure that the edge is beyond of the dynamic envelope of the freight cars. While this guarantees that the platform will not be struck by passing cars, it often introduces an excessive gap (beyond 3 inches per ADA requirements) for boarding commuter trains (7).

Additionally, shared operations can lead to certain maintenance issues in relation track position and geometry. Traditional ballasted track is subject to movement due to heavy freight operations. The degree to which the track moves often depends on factors such as type of ties, size of rail, quality of ballast, sub-ballast characteristics, climate, and freight tonnage on the line. The movement can affect the track in various ways including changing the position both vertically and horizontally. This can be a significant problem with the tight gap tolerances set forth by ADA. Regular measurement and maintenance is required to ensure that gap dimensions are acceptable along the entire length of each platform. This can be both costly and time consuming. An additional possible solution could involve using concrete slab track in station areas. This potential improvement could be costly as well but involve relatively little maintenance for keeping the gap dimensions within tolerances. The solutions that a transit agency chooses to pursue depends on funds available and preferences of the partner railroad that shares the corridor (2). Transit agencies throughout the country and the world have made attempts to correct the excessive gap problem. The most successful solutions may vary between each platform along the same line. This can make a “one size fits all” solution very difficult to develop. One of the newer techniques that has emerged is known as a gauntlet track. This treatment was discussed in detail in a previous section. It should be noted that currently both Portland’s West Side Express Service (WES) and NJ Transit’s Raritan Valley Line have at least one operational gauntlet track section (7).

**OTHER CONSIDERATIONS**

This paper has focused specifically on the technical design aspects of the platform, however it should be noted that safety at the platform-train-interface (PTI) involves additional factors as well. The two primary additional considerations are transit operations and passenger characteristics. Previous studies by New Jersey Institute of Technology and the Rail Safety and Standards Board (RSSB) out of the United Kingdom have focused extensively on passenger characteristics in relation to PTI safety. Some major
findings include that children and those passengers over the age of 50 often have a higher risk of injury. Additionally females have a higher risk of injury around the PTI than males. Lastly, distracted and intoxicated passengers are much more likely to be injured or killed than those who are aware of their surroundings (5, 20).

Operational factors also can have a significant effect on passenger safety. From the TCRP A-40 webinar and various stakeholder surveys it has been determined that one of the biggest operational factors that can improve safety is public relations campaigns. The importance of educating passengers and employees about platform safety was emphasized quite frequently in discussions and surveys. Effective techniques include automated announcements on trains and platforms, safety videos, posters, and placards. One unique idea that was employed by Metro in Melbourne, Australia involved the creation of an internet based video ad campaign entitled “Dumb Ways To Die”. Through the use of humor and rather graphic images of animated characters dying in what were determined to be stupid ways, the message is conveyed that people should be careful around railroad tracks and stations. While this specific video might not be appropriate for all audiences, the use of humorous videos to convey safety messages could be potentially very effective on transit users. A similar effort was undertaken by various airline companies recently in efforts to have passengers pay closer attention to the preflight safety briefings. Indications thus far seem to suggest these methods are better than traditional briefings (7).

CONCLUSIONS AND DISCUSSION

A number of technical design factors that are related to platform-train-interface (PTI) safety have been discussed based on stakeholder input and an extensive literature review. From the background information available some useful conclusions could be made. As previously discussed, platform size and shape can have a significant impact on safety. In general, as the size of the platform increases the possibility of crowding is reduced and thus overall safety improves. It was also determined that straight platforms present fewer problems in relation to horizontal gaps than curved platforms. It should also be noted that curved platforms are more often a problem on legacy systems and not recently constructed lines. Certain gap mitigation technologies have started to be used more frequently, and these include; gauntlet tracks, movable platforms, and rubberized platform edges. In each case, the gap fillers need to be approved by the host railroad for compatibility. Which technology is employed is largely a function of mode type and specific platform characteristics. Through the literature review and interviews it was found that horizontal gaps tend to present more significant problems than vertical gaps between the platform and train. It has also been determined that gaps between cars or vehicles can be a serious safety problem to both visually impaired and distracted passengers.

Intrusion prevention and detection has also been identified as an important factor in relation to PTI safety. The most effective method of prevention is the implementation of platform screen doors (PSDs) on the platform edge. Ideally PSDs would be installed on new platforms, as there are often technical challenges and high costs associated with retrofitting doors on existing platforms. Furthermore, it was found that passengers were generally against the PSDs if it meant that there would be a fare increase. Intrusion detection is another potentially important technology that continues to be explored. Laser based detectors on both the edge of platforms and on the track have been identified as a new technology for intrusion detection. Continued development and additional research is needed to improve these systems.
It should be further emphasized that platform-train-interface (PTI) safety issues are mode specific and potential solutions for each mode can vary greatly. Heavy rail has issues that are derived from passenger behavior. Light rail and streetcar have challenges related to sharing platforms with other modes. Commuter rail generally encounters the most technical problems that related to PTI safety with shared freight operations. Gap filling technology continues to be on the forefront of commuter rail safety. While the technical design aspects are important to PTI safety, passenger characteristics and operational aspects must also be considered. Extensive public outreach campaigns and employee training should be undertaken to improve awareness of potential safety issues that relate to the platform-train-interface. In specific passenger distraction and intoxication are two significant problems that should be addressed by transit operators.

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Figure 2 Bollard Between Car Barrier in Los Angeles, CA.

Figure 3 Elastic Band Between Car Barriers in San Francisco, CA.

Figure 4 Edge Warning Light Treatment on Washington D.C. Metro.

Figure 5 Half Height Platform Screen Doors on Taipei Metro.
FIGURE 1 Gauntlet Track at Station in Portland, OR (Ken Kirse).
FIGURE 2 Bollard Between Car Barrier in Los Angeles, CA.

http://farm3.static.flickr.com/2563/3677271903_51528ed0d6_m.jpg
FIGURE 3 Elastic Band Between Car Barriers in San Francisco, CA (9).
FIGURE 4 Edge Warning Light Treatment on Washington D.C. Metro.

https://c1.staticflickr.com/7/6101/6345516728_35ae4f6206_z.jpg
FIGURE 5 Half Height Platform Screen Doors on Taipei Metro.

http://www.securityworldmag.com/data_file/board/PSD_1.jpg