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Customer Behavior Relative to Gap Between Platform and Train

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Submitted by

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16. Abstract

Managing gap safety at the train platform interface has been an on-going concern for passenger rail systems. The major questions this research seeks to answer are what customer behaviors are associated with the risk of gap injury incidents and what are potential ways to reduce these behavioral risks. To answer these questions, the research approach is two pronged. The first prong analyzes and reviews the NJ TRANSIT Rail accident data and reports to gain a clear picture of the accidents in relation to demographic, seasonal, and temporal characteristics. The second prong involves observational studies of passengers boarding trains to identify behavioral patterns that are associated with risk of gap accidents.

An analysis of gap injuries on NJ TRANSIT Rail found that for 2005 to 2008, gap injuries accounted for 25 percent of passenger injuries on NJ TRANSIT Rail. The majority of gap injuries occur during the AM and PM peak periods. For gap injuries the percent of injuries peaks for the very young, under 10 years old. For both gap and non-gap injuries, the majority of the injured were women. Sixty-six percent of gap injuries occurred while passengers were boarding. The study indicates that young children were particularly vulnerable to gap injuries while detraining. Seventy-eight percent of detraining passengers and 88 percent of boarding passengers were observed to look down while detraining or boarding. Based on the analysis of the data, recommendations on strategies for reducing gap accidents include additional Passenger Information, Platform and Train Treatments, Training and Public Awareness Campaign.

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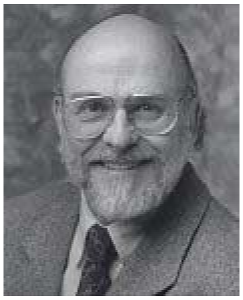

This report is dedicated to Edward K. Morlok, Professor Emeritus from University of Pennsylvania who worked as a consultant on this project. Dr. Morlok provided direction in the analysis approach and whose editing comments and revisions were used to author sections throughout the entire report.

Dr. Morlok passed away two weeks after the end of this research project after a long struggle with cancer. We echo the words of his wife, Patricia Campbell Morlok, that "…he was above all things a gentleman". The research team is grateful to have had the opportunity to work with Dr. Morlok on this research.

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INTRODUCTION

Managing gap safety at the train platform interface has been an on-going concern for passenger rail systems. The major questions this research seeks to answer are what customer behaviors are associated with the risk of gap injury incidents and what are potential ways to reduce these behavioral risks. To answer these questions, the research approach is two pronged. The first prong analyzes and reviews the NJ TRANSIT Rail accident data and reports to gain a clear picture of the accidents in relation to demographic, seasonal, and temporal characteristics. The second prong involves observational studies of passengers boarding trains to identify behavioral patterns that are associated with risk of gap accidents.

SUMMARY OF THE LITERATURE REVIEW

The literature search found that while the thrust of analysis of gap-related injuries is one of human factors, no direct behavioral study of passengers crossing the gap were uncovered. Human factor analysis identified demographic issues (age, disability) and behavior issues (rushing, pushing, distractions caused by children, luggage, cell phones) that may contribute to gap accidents at railroads. Platform conditions, including crowding, wetness, size of gap, all contributed to the number and occurrence of gap accidents. Mitigation measures used to treat gap accidents included staff training, public awareness campaigns, staff deployment, dwell times and the use of yellow lines.

SUMMARY OF THE WORK PERFORMED

Gap Injury Analysis

An analysis of gap injuries on NJ TRANSIT Rail found that for 2005 to 2008, gap injuries accounted for 25 percent of passenger injuries on NJ TRANSIT Rail. From 2005 to 2006, gap injuries increased by 97 percent to 75 gap injuries compared to a 3 percent increase in non-gap injuries. Between 2006 and 2007 both gap and non-gap injuries increased by 11 percent. Between 2007 and 2008 there was a 30 percent reduction in gap injuries compared to a 10 percent reduction in non-gap injuries. The reduction may be attributed to efforts on the part of NJ TRANSIT Rail to alert passengers to the gap.

<u>Time of Injury</u>

The majority of injuries occurred during the AM and PM peak periods. A higher percentage of gap injuries in the AM and PM Peak periods than at other times reflected passenger volumes. Gap injury rates by time of day would have been expected to have been lower during the peak period than for other periods given the typical peaking of commuter rail passenger traffic during the peak period.

Month of Injury

The highest percentage of gap injuries occurred during October to December. The highest percentage of non-gap injuries occurred during July to September. The data showed differences in the percentage distribution of gap and non-gap injuries by month. Passenger volumes by month**,** lighting, weather, level of distraction and other behavioral factors that change by month may explain the specific characteristics that lead to differences in gap and non-gap injuries by month.

Day of Week

Almost 80 percent of gap injuries occurred during the weekday, compared to 86.5 percent of non-gap injuries that occur during the weekday. The peaking of gap injuries on Wednesdays may be associated with increased passenger volumes on Wednesdays.

Age of Injured

For gap injuries the percent of injuries peaks for the very young, under 10 years old, then increased with age until the 30-40 year group. After this age group the percent of injuries remained flat for older age groups. For non-gap injuries, the highest percent of injuries occurred for ages between 50 and 60 years old. The data indicated that unlike non-gap injuries, gap injuries did not increase with age. Gap injuries associated with the very young may be attributed to distraction, shorter strides and general unfamiliarity with train boarding and detraining. Gap injuries associated with 30 to 40 years old may be a result of higher number of passengers in this age category.

Gender of Injured

For both gap and non-gap injuries, the majority of the injured were women. Gap injuries associated with women passengers were more likely to occur during October to December, on a Thursday, during either the AM or PM peak period and be associated with women aged 30 to 50 years old.

Boarding and Detraining

Sixty-six percent of gap injuries occurred while passengers were boarding. Seventy percent of gap injuries for female passengers occurred while boarding compared to 56 percent for male passengers. The largest differences between boarding and detraining passengers occurred for those under 10 years. The study indicated that young children are particularly vulnerable to gap injuries while detraining.

Stations with Highest Gap Injuries

Newark Penn Station and New York Penn Station had the highest number of gap injuries at 28 and 26 gap injuries, respectively. The stations with the highest number of gap injuries were also the stations with the highest number of boarding and detraining passengers. For most of the stations, the highest percent of gap injuries occurred during boarding. Long Branch and Secaucus Junction were the two stations where the majority of gap injuries occurred during detraining.

Summary of Passenger Observational Surveys

Seventy-eight percent of detraining passengers and 88 percent of boarding passengers were observed to look down while detraining or boarding. Long Branch was observed to have the lowest percentage of passengers looking down and Secaucus Junction was observed to have the highest percentage of passengers looking down.

The largest type of distraction observed were passengers carrying luggage. For the stations studied, passengers with luggage were more likely to be boarding than detraining. Cell phone usage was not a large distraction as the high noise levels on the platform made cell phone use impractical.

Summary of Gap Sizes

NJ TRANSIT Rail measured existing vertical and horizontal gap sizes at all tracks with high level platforms. From this data, the maximum gaps at NJ TRANSIT Rail stations ranged from 24.45 in. at Princeton Junction (NJT) Station to 1.75 in. at New York Penn Station. The excessive gap at Princeton Junction Station is associated with the tight track curvature of the Princeton Line, and only affects equipment with center doors. Passengers board and alight only at end doors at Princeton Junction Station. No clear relationships were observed between the maximum gap size at each station and the gap injury frequency or rate.

Recommendations

Based on the analysis of the data, recommendations on strategies for reducing gap accidents at NJ TRANSIT Rail stations were developed. The recommendations sought to address mitigating factors that contribute to these accidents and are recommended for implementation if feasible and when budget permits.

Passenger Information

- Use of additional platform personnel during peak periods and at stations with high gap injuries.
- Use of easily viewed platform monitors indicating the train and track numbers, and time of departure. Large signs and consistency in the placement of track number signs.
- Use of pre-recorded messages to "Watch the Gap" that is played while passengers are waiting at the platform and while on the train.

Platform and Train Treatments

- Use of reflective markings at train door thresholds and at locations of the platform with large gaps.
- Use of color to bring attention to existing train hand rails.
- Reduce unusually large gaps where this is feasible given train clearance requirements.

Training

- Involve train conductors in the development and deployment of solutions to reduce gap injuries.
- Providing a greater awareness of NJ TRANSIT Rail's current gap injury rates and the target goal for reducing these injuries.
- Alerting conductors to the passenger types and stations where assistance may be needed.

Public Awareness Campaign

The research indicated that women are more likely to be involved in a gap injury and also more likely to not look down while boarding and detraining compared to men. For this reason a targeted public awareness campaign should be developed to address this group.

INTRODUCTION

Managing gap safety at the train platform interface has been an on-going concern for passenger rail systems. A spate of documents from the Federal Railroad Administration (FRA) during 2007 underscores the priority FRA is giving to this problem. Responding to the death of a Long Island Railroad (LIRR) passenger in 2006 when she fell into the gap, the FRA established a task force to address concerns relating to gap safety (Congressional Testimony of J. Boardman, Jan. 30, 2007 and J. Strang, May 22, 2007). Recently, the FRA issued a document proposing comprehensive strategies for managing the problem (FRA, Dec., 2007).

The pervasiveness of the problem of customers injuring themselves in falls between the train and platform is seen in a 2006 study by Great Britain's Rail Safety and Standard's Board (RSSB). This study documented that 22.1 % of customer injuries occurred when passengers fell between the train and platform. In Newsday (January 19, 2007), LIRR officials were quoted as saying that 38% of its platforms had gap problems. NJ TRANSIT Rail faced the problem of a significant portion of customer injuries (26%) occurring when the customer fell between the platform and the train according to 2006 data.

Those data have prompted the current research investigating factors associated with risk of gap injury incidents and identifying potential ways to diminish this problem at NJ TRANSIT Rail. The focus on customer behavior is a frequent approach to mitigating customer safety issues at the gap. This approach was taken by the RSSB (2006) in using a human factors approach to understanding the demands of crossing the gap and in part in LIRR Acting President Raymond Kenny's summary to the FRA (2007) regarding LIRR proposals for reducing gap injuries.

Background

NJ TRANSIT's commuter rail network consists of 11 lines, 162 stations and a fleet of over 1,000 passenger cars. In addition, several railroads hold trackage rights agreements to operate freight service on NJ TRANSIT Rail owned lines. To accommodate the variety of train types using the system, it is necessary to allow for "gaps" between the train and platform to ensure trains to operate safely at authorized speeds. Figure 1 shows the types of gaps studied in this research. Narrow gap sizes could result in trains striking the platform, while wide gaps would lead to difficulties in passengers boarding or detraining at the platform.

The focus of this study is on high level platforms (HLPs), defined as platforms which are approximately the same level as car floors, allowing for "level boarding." In fact, the design height of such platforms is 48 in. above the top of the rail[1], somewhat lower than the typical car floor height of 51 in. With a 10 ft. wide car floor (at the door opening), the

[1] NJ TRANSIT Rail, Office of Chief Engineer – Maintenance of Way, 1983.

design setback of a HLP results in a 7 in. horizontal gap between car and platform, on straight (tangent) track. The gaps are increased somewhat on horizontal and vertical curves. In practice, platforms and track shift due to weather, resurfacing, etc., and the car floor height can vary with load and track conditions, and thus the vertical and horizontal gaps between a platform and car will vary of necessity.

Many rail stations—including some stations on NJ TRANSIT Rail-- have the other common platform type, termed a Low Level Platform (LLP). It is, by design, only 8 in. above the rail and requires steps to the seating area of a rail car. This type of platform is not the focus of this study; NJ TRANSIT Rail has been replacing many LLPs with HLPs as funds and conditions permit.

The Department of Transportation's Americans with Disabilities Act Statute and Regulations provide that platforms must be "readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs (49 CFR Part 37, Appendix A, 10.3.1 (9))." At stations with high level platforms, there may be a gap of no more than 3" horizontal and 5/8" vertical between platform edge and entrance to the rail car. However, currently no passenger rail system in the U. S. has been able to achieve this without the use of manually-operated "bridge plates."

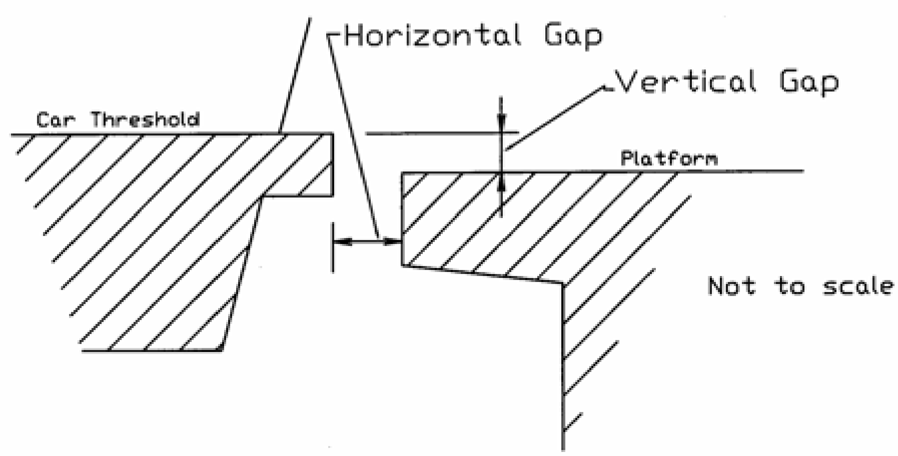

Figure 1. Horizontal and Vertical Gap between Train and High Level Platform

RESEARCH OBJECTIVES

The objectives of this research are:

1. Review the previous research and organize the information so gap-related injuries at NJ TRANSIT Rail can be understood in context

2. Analyze accident data from NJ TRANSIT Rail and compare it to other appropriate commuter rail properties

3. Observe customer behavior boarding and alighting trains and link behavior to risk of accidents

4. Identify approaches to mitigating accident risk using both “soft approaches” such as human factors, signage, and messages as well as “hard approaches” such as design issues

5. Make recommendations of appropriate factors to mitigate accidents in the context of implementation, cost and regulatory issues such as ADA.

RESEARCH APPROACH

The major questions this research seeks to answer are what customer behaviors are associated with the risk of gap injury incidents and what are potential ways to reduce these behavioral risks. To answer these questions, the research approach is two pronged. The first prong analyzes and reviews the NJ TRANSIT Rail accident data and reports to gain a clear picture of the accidents in relation to demographic, seasonal, and temporal characteristics. The second prong involves observational studies of passengers boarding trains to identify behavioral patterns that are associated with risk of gap accidents. The specific tasks performed include:

Task 1. Literature Search.

Task 2. Gather data and perform analysis of NJ TRANSIT Rail data.

Task 3. Observe passengers under varying conditions.

Task 4. Examine state of practice at other large commuter rail systems.

Task 5. Make recommendations based on analysis of the data, and state of practice.

The research began with a comprehensive review of literature on the gap in platform – train interface. Our search included traditional research literature as well as other documents that refer to the problem. The literature review includes both examination of gap related injuries and proposed actions to reduce these injuries. Following the literature review, we analyzed data from NJ TRANSIT Rail to ascertain the extent and the trends regarding customer falls. In addition, we have captured data from the FRA which includes comparison of NJ TRANSIT Rail with LIRR and Metro-North. The data analysis in combination with the literature search directed us toward constructing the structured observation forms for systematic direct observations of passengers boarding and alighting. Our behavioral data was analyzed to gain insight into passenger activities that could put them at risk traversing the gap. Following comprehensive analysis of data from the three sources, quantitative, qualitative and direct observation, we propose a set of recommendations tailored to the particular circumstances at NJ TRANSIT Rail. Recommendations are made in the context of several factors including ease of implementation, cost, compatibility with rail freight service and additional factors which emerge in the course of the research.

SUMMARY OF THE LITERATURE REVIEW

Despite the fact that accidents regarding boarding and alighting are a problem across a variety of modes (bus, car, and train), research in this specific area appears to be sparse. This is especially the case regarding trains. Morlok's 2004 study discussed below dealt with platform and train entranceway design. Great Britain's Rail Safety and Standard's Board (RSSB) 2006 study examined accidents and engaged in a hierarchical task analysis regarding passengers crossing the platform train interface. After reviewing the existing research and other pertinent documents, we propose a literature review structure which looks at factors related to accidents, attempts to reduce gap-related injuries and the impact of training and technical fixes.

Accidents related to the Gap Problem

Human Factors – RSSB Study

From a safety perspective, understanding the behavior that contributes to the safety problem is a critical component to reduce the hazard. Using such an approach, Great Britain's Rail Safety and Standards Board (RSSB, 2006) undertook an accident and a task analysis to gain better understanding of accidents at the train platform interface. Their research examined gap-related passenger accidents within the rail system in England. Data for the study came from incidents reported to the RSSB during the period covering Jan. 2001 to May, 2005.

The RSSB study included all accidents. The categories were: train door closing on passengers, passengers falling between the train and platform (gap accident), passengers falling out of the train onto the track at the station, passengers falling off the platform and being struck by a train, passengers getting injured while boarding or alighting from the train, and passengers being struck by a train while on the platform. Of the 4,287 gap related accidents reported between January, 2001 and May 2005, falling into the gap accounted for 22.1%, alighting accidents were 21.7%, door closings were 21.1 % and boarding accidents were 15.7%.

In addition to accident analysis, the study entailed a task analysis using workshops with key stakeholders. These included members from Network Rail, Train Operating Companies, Department for Transport, passenger representatives and experts in needs of disabled users. The workshops were used to get qualitative rankings of risk associated with tasks produced in the hierarchical task analysis as well as mitigations relating to these tasks.

Risk Factors

Passenger factors associated with an increase in risk of an accident included: mobility, being elderly, having disabilities (visual impairment), being accompanied by small children or incidents occurring to small children, behavior of other passengers such as pushing or jostling, carry luggage and other articles, alcohol, degraded platform conditions such as crowding, wet platforms or uneven platforms, and stepping distances.

Behavioral Factors

Mentioned as reasons for accidents include rushing for trains and distractions such as talking to a companion or using a cell phone. This is particularly true for door closing incidents where people ignored warnings to stand clear of the door. An accompanying door closing alarm acted as a prompt for passengers to rush in their attempts to board. (This phenomenon has been observed regarding driving behavior at yellow lights where drivers speed up to cross the intersection rather than slow down in anticipation of a red light.). Examination of the data suggested that the majority of the accidents are driven by human factors and not rolling stock or train operations.

Other Factors

Findings indicated a strong correlation between station usage and accident incidents. That is, the heavier the traffic at the station, the more accidents occurred. This is similar to the occurrence of gap accidents at NJ TRANSIT Rail

Great Britain's Department of Transport's research on step size comfort suggests many stepping distances were outside the area of comfort for mobility impaired passengers. Step heights and gaps were more of a problem for getting off the train than for getting on, with (as mentioned earlier) alighting accidents being almost 40% more frequent than boarding accidents. Vertical gaps in Great Britain are often much larger than those in the US, and this may at least partly explain the difference. Interestingly, accident data from NJ TRANSIT Rail has revealed more frequent boarding than alighting accidents. The RSSB study indicated one thousand eighty (1080) platform-train-interface (PTI) incidents occur each year, one for every 1.6 million traverses. The low incidents level is due to much mitigation already in place.

Conclusions of the RSSB Study

The number of PTI incidents was low compared to the number of traverses. Incidents were linked to traverses. Physical characteristics at stations in combination with passenger characteristics affected the likelihood of an accident. Blanket adjustments to physical characteristics were not seen as the most cost effective way to mitigate accidents. Where the gap was large, risk should be minimized by redesign when the track through the station is planned to be replaced and realigned. Taking passenger characteristics into account may be more efficient for reducing gap accidents for most locations. Suggested mitigations are discussed elsewhere in this review.

Additional Human Factors - Delft University Simulation

The research team of Daamen, Lee, and Wiggengard at Delft (The Netherlands) University of Technology studied passenger behavior both boarding and alighting trains. To do this, Daamen, Lee, and Wiggengard (2008) set up a simulation room to experimentally examine boarding and alighting behavior. The simulation room arranged at Delft University of Technology consisted of two vehicle blocks representing train vestibules. This simulation allowed the researchers to experimentally manipulate height between platform and vehicle, stepping gap, door width, luggage load and time pressure. While age and gender of the "passenger subjects" were recorded, this research did not report their impact. Eighty individuals took part in the research but no information was reported regarding recruitment methods. Nor was there report of the age and gender breakdowns for this sample. Using video monitoring of passenger movement on and off the simulated train vestibules, the researchers reported that luggage load was more related to a decrease in door capacity than either an increase in horizontal or vertical gap. While this study did not examine gap accidents it did confirm that luggage handicaps the passenger while boarding or alighting and was consistent with the RSSB task analysis.

Summary of Human Factors

Passenger characteristics and behavior were judged to be a more frequent contributor to platform-train gap accidents than the physical characteristics of the rail cars and the stations. There may be some instances where the gap is sufficiently large that it would require station or train redesign. However, more was judged to be gained from examining passenger characteristics and behavior as a way of understanding the accident process.

Design Factors

Two studies were found that made reference to design factors. The first by Harris and Anderson (2007) compared international boarding and alighting rates. They noted that both rolling stock issues (e.g. the number of train car doors and door width) and platform characteristics (e.g. height and width of the platform gap) impacted the rates of passengers getting on and off trains. While this study looked at boarding and alighting in a variety of metro systems around the world, the researchers found no differences in boarding and alighting rates due to cultural attributes. At least in this study, the more concrete factors such as train doors and number of passengers were more powerful in explaining the rates of alighting and boarding than those more abstract ones such as culture.

The second study was by Morlok, Nitzberg, and Lai (2004). This research looked at the relationship between platform design and passenger and employee accidents, Morlok, Nitzberg, and Lai compared accident rates among three platform and two car door arrangements. Specifically, they examined accident rates at thirteen U.S. commuter rail systems from 1995-2000. The platform designs included high level platforms, low level platforms and systems with a combination of both high and low level platforms. Car door entrance ways in this study had either manually operated doors and traps or remotely controlled doors permitting all doors to be closed except while passengers are boarding or alighting. Analysis of the passenger accident data disclosed that high level platform with remotely controlled doors on the trains yielded the lowest accidents rates followed by low level platforms with remotely controlled doors. Systems with a combination of high level and low level platforms with manually operated doors (and vestibule traps) yielded the highest accident rates. In particular, on these manually operated door systems, doors are often open (with traps raised) when a train enters and leaves a station, contributing to a safety hazard.

Operational Factors

In our literature review we found no study which directly examined train operation on gap accidents. However, research on train dwell time suggested that there were instances where longer dwell times, particularly when there were heavy passenger loads, may reduce gap accidents. The RSSB study suggested longer dwell times at peak loads as a way of mitigating platform train incidents. A report to the FRA by Raymond Kenny (2007), (Acting) President of the LIRR also discussed train operations as way to mitigate accidents. More specifically, he suggested zoning cars so that at some locations certain car doors would be kept closed to prevent passengers from encountering difficult gaps to cross. Another operational change he suggested was that of train stopping patterns. That is, trains adjust where they stop at problematic stations to a location where wider gaps are avoided. Use of added platform personnel (conductors) was yet another suggestion made by Mr. Kenny. These conductors would be used during times of heavy boarding to communicate with train crews and to assist passengers as needed. The use of extra personnel on the platform was also mentioned by the RSSB study as a way to mitigate accidents.

Mitigation Measures

A variety of approaches to mitigating passenger risk at the gap have been suggested. The Great Britain RSSB study used key stakeholders to rank the effectiveness of a variety of mitigations. Ranked mitigations from the RSSB study follow:

Staff Training

The highest ranked activity was training staff on awareness of passenger needs. While it is discussed below as a separate topic given the importance the RSSB study attached to it, in general, staff should be made aware of accident data and those demographics and situations that put riders at higher risk for falling.

Public Awareness Campaigns

The second most highly ranked mitigation was that of safety campaigns for riders regarding safe boarding and alighting behavior and the impact it can have on themselves and others. Through the use of signs and public announcements, passengers would have their awareness raised of the gap crossing risk. Such campaigns are an on-going process at stations in the London Underground system. More of this topic is discussed below.

Staff Deployment

Staff should provide customer assistance when a high risk situation occurs. Platform staff should be available to assist those who need help boarding. While adding cost, this may be the most cost effective way to mitigate accidents at peak times.

Other Mentioned Mitigation Measures

The report suggested that increasing dwell time should be considered especially during heavy usage or times when accidents were more likely to occur. Also mentioned were ensuring yellow lines were intact and in a good state of repair and providing correct, timely user friendly information.

Training

Most prominently mentioned in the literature from the RSSB study (2006) was that of staff training for both train crew and station staff. The Rail Industry Advisory Committee (RIAC) Minutes of Jan. 10, 2006 and Dec. 13, 2006 also reaffirm the importance of training. Staff should be trained regarding passenger risk factors such as age, carrying luggage, and crowding. Staff should be made aware of data regarding platform train incidents and the situations in which they are more likely to occur. Another area suggested for staff training was assertiveness. This training could assist staff when stations become crowded and passengers are rushing for trains thereby increasing risk. The RSSB report suggested that a mechanism be available for exchanging best practices and these be disseminated to platform and train staff.

Platform Design

Platform Location

The current U.S. Department of Transportation ADA section 504 regulation (49 CFR §27.7) regulation (2007) for new stations on commuter and intercity rail systems provides for a full platform covering the length of the passenger boarding area. Its design should permit level boarding to all train cars that are accessible when the train stops. Moreover, the regulations (49 CFR Part 37, Appendix A, §10.3.1(9)) provide for a horizontal gap of no more than three inches and a vertical gap of no more than 5/8 inches. The Department of Transportation recognizes that meeting this regulation is not feasible for a variety of reasons particularly regarding the gap provision. However, the thrust is to provide entry level boarding even where the gap exceeds the guidelines.

For the purpose of boarding those with disabilities, a bridge plate is recommended. These are commonly used in the US for boarding and alighting at high level platforms whenever the gap posses an impediment, as it would typically for a passenger in a wheelchair, and a passenger with roll-on luggage.

Yellow Lines

A frequent suggestion regarding platform design is the use of yellow lines to call passenger attention to the edge of the platform. (RIAC notes, Jan. 10, 2006; RSSB T426, 2006, Kenny Report to the FRA, 2007). Currently the RSSB is undergoing an evaluation of the effectiveness of yellow lines on non-high speed platforms (RSSB, 2008). LIRR however has gone a step further and has added red stripes and stenciled "watch the gap" to call attention to the platform edge as shown in as shown in Figure 2. The second photo (Figure 3) also shows a yellow stripe at the edge of the train door threshold as well. Figure 4 illustrates NJ TRANSIT Rail's stencil of Watch the Gap on the train platform. Figure 5 shows additional views of the LIRR Flatbush Avenue station gaps of 10 inches and Figure 6 shows a second view of the matching yellow stripe at train edge and the platform edge is seen in this photo of the Syosset station.

Figure 2. LIRR Flatbush Ave. Station with Red Lines Underscoring Wider Gap

Figure 3. LIRR stencils "Watch The Gap" to Yellow Lines

Figure 4. NJ TRANSIT Rail "Watch The Gap" stenciled to Yellow Lines

Figure 5. Additional Views of LIRR Flatbush Ave. Station Gaps of 10 inches

Figure 6. Matching Yellow Stripe at Train Edge

In another attempt to mitigate the problem through platform design, MTR Corporation which operates Hong Kong's rail and metro systems, installed rubber moldings to the platform edge to reduce the gap. Additionally, this system has platform screen doors as an additional safety mechanism to reduce to risk of accidents and to enhance station security (see Figure 7) (RIAC, 2007).

Figure 7. Platform Screen Doors at Hong Kong's Tiu Keng Leng Station

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Car Design

<u>Reducing the Gap</u>

Some railroads have extended the floor of the car outward at the doorway to reduce the gap, particularly when the car is relatively narrow resulting in a large gap. One example was such use on the exclusively high level platform division of the Chicago commuter system, and on one similar line in the Philadelphia area (on which recently purchased cars have the same feature). By this means the gap can be reduced from the nominal 7 in. for a high level platform with a 10 ft. wide car. On some systems certain platforms may be unusually close to the rail (as at locations with no freight service), and thus this option would require modification of those platforms. It is recognized that NJ TRANSIT operates on other's rail lines, so coordination between the various organizations would be required.

Covering the Gap

In order to provide for easy entry into various railroad and other transit vehicles, various devices have been developed and used to completely cover the gap between vehicle and platform. Already mentioned is the use of manually placed bridge plates on commuter and intercity rail systems. These are usually stored at stations and deployed by a member of the train crew whenever a person on a wheelchair or other person needing the device is trying to board of alight. A disadvantage of the manual deployment is the delay to the train.

A similar problem exists on other types of transit systems, and a variety of devices have been manufactured to deploy a bridge plate without the need for the vehicle operator to leave the driving cab or location. With few exceptions, these are installed on the vehicle. Some are activated at all stops, while others are deployed only upon action by the vehicle operator or the passenger. Sometimes these are installed at all doors, while in other cases they are located only at one or a few doors. A good introduction to these devices, with emphasis on light rail but with some discussion of commuter and intercity railroads, is given by Lewalski (1995).

While the primary purpose of these devices is to enable mobility challenged passengers (including those with luggage, small children, etc.) to board and alight easily, they have the effect of reducing dwell times where such passengers are present, and probably also reduce the risk of accidents. Unfortunately, no empirical data on any reductions in injuries or risk were found.

Public Awareness Campaigns

Increasing public awareness through signage and announcements is yet another method employed to mitigate risk at the platform-train interface. Prominently displayed signage to catch the attention of passengers is a way to assist them in focusing on their own boarding and alighting behavior. Figures 8 and 9 show photos of LIRR's signage. Figures 10 and 11 show NJ TRANSIT Rail's signage. Figure 12 demonstrates NJ TRANSIT Rail's electronic safety message. Figure 13 shows the NJ TRANSIT Rail's train information system at Newark Penn Station.

Figure 8. LIRR Public Awareness Posters

Figure 9. LIRR Multi-media Approach to Public Awareness

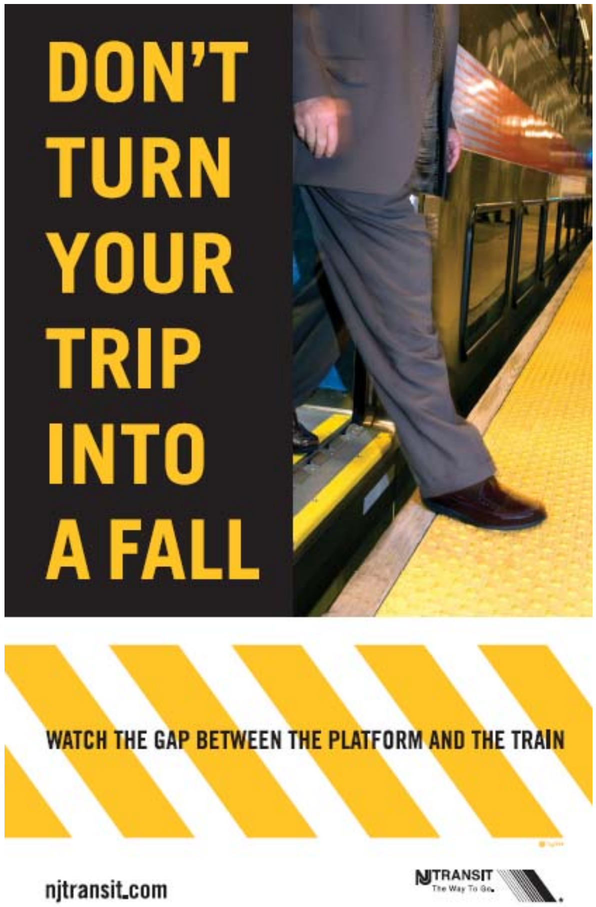

Figure 10. NJ TRANSIT Rail Public Awareness Poster on Track

Figure 11. NJ TRANSIT Rail Equipment Gap Signage

Figure 12. NJ TRANSIT Rail Electronic Public Awareness Signage

Figure 13. NJ TRANSIT Rail Train Information System – Newark Penn Station

Platform Personnel

Mentioned in several references was the use of platform personnel to monitor and assist passenger in boarding and alighting (RSSB T426, 2006, Minutes of RIAC Human Factors Working Group, May 8, 2007, Kenny Report to the FRA, 2007). Figure 14 is a photo from the Kenny Report showing deployment of such personnel.

Figure 14. Example of Platform Personnel

Summary of Literature Review

The major thrust of research pertaining to "gap issues" is that of collecting accident data (RSSB, 2006, Kenny Testimony, 2007, NJ TRANSIT Rail, 2008) and describing real and potential mitigations. Conclusions from Great Britain's RSSB study and other research supposes that passenger behavior along with passenger demographics explain most of the gap accidents. Our literature search disclosed no behavioral research examining what passengers are actually doing as they board and alight trains.

Three types of investments have been used that presumably reduce the risk on gap injuries. One is to install yellow lines, or other markings, along the platform and doorway floor. Closely related are signs and announcements warning of the gap. These represent rather modest investments. A second, presumably more expensive approach is the extension of platforms to reduce any abnormally large gaps, though this is limited by safety considerations and cannot completely eliminate the gap. The third, presumably even more expensive, is to install powered bridge plates on the rail car. Such installations have been motivated primarily by considerations of making entry easier for mobility limited passengers. No research was found that assessed the reduction in accidents (if any) that is associated with any of these investments.

Another approach is to deploy platform personnel, who would warn of the dangers and presumably assist passengers if necessary. This represents a continuing operating cost, but may be warranted at some stations. Again, no research into actual results with respect to injuries was found.

In one related study of passenger behavior, Daamen, Lee, & Wiggengard, (2008), found that luggage impeded passengers passing readily through train doors. Luggage in fact was a greater impediment than an increase made to the vertical or horizontal gap. Impediment was measured in time to board or alight.

SUMMARY OF THE WORK PERFORMED

Gap Accident Analysis

To provide the Federal Railroad Administration with accurate information concerning the hazards and risks on the Nation's railroads, all railroads in the U.S., except for certain types of railroads, must collect information on accident/incident and injury/illness conditions. Using data collected from NJ TRANSIT's Rail Safety Department an accident analysis was performed for injuries occurring on NJ TRANSIT's property for 2005 to 2008. These accidents include both reportable and non-reportable accidents. Reportable accidents refer to FRA-reportable personal injuries based on medical treatment received.

Overview of Passenger Gap and Non-Gap Injuries

Table 1 shows the number of passenger gap and non-gap injuries by year from 2005 to 2008. Between 2005 and 2008 there were a total of 1020 injuries on NJ TRANSIT Rails. Twenty-five percent or 254 injuries were classified as "gap injuries" compared to 766 non-gap injuries. In 2005 there were 38 gap injuries, compared to 182 non-gap injuries. From 2005 to 2006, gap injuries increased by 97 percent to 75 gap injuries compared to a 3 percent increase in non-gap injuries. This large increase in gap injuries from 2005 to 2006 may be as a result of recent media attention brought to these types of injuries that were now being classified as "gap injuries". Between 2006 and 2007 both gap and non-gap injuries increased by 11 percent. In 2008 there was a 30 percent reduction in gap injuries compared to a 10 percent reduction in non-gap injuries.

The reduction may be attributed to efforts on the part of NJ TRANSIT to alert passengers to the gap. The Platform/Train Gap Management Program includes several elements which have been implemented or are in the process of being implemented including:

- On-board announcements by traincrew through enhanced language.
- On-board automated PA system for gap message.
- Automated gap message on station platforms.
- Internal and external car signage with gap message.
- Development of a platform/gap awareness training for new employees.
- Platform stencil with gap message.
- On-board posters and brochures containing the gap message.
- Utilization of platform PA system for gap message.
- Measurement of vertical/horizontal high-level platform clearances to ensure the gap between train and platform is maintained to NJT standard.

Table 1. Number of Passenger Gap and Non-Gap Injuries by Year

Year	Gap Injuries	Non-Gap Injuries	Total	% of Gap Injuries	% Change in Injuries from Previous Year	
					Gap Injuries	Non-Gap Injuries
2005	38	182	220	17.3%	-	-
2006	75	188	263	28.5%	97.4%	3.3%
2007	83	208	291	28.5%	10.7%	10.6%
2008	58	188	246	23.6%	-30.1%	-9.6%
Total	254	766	1020	24.9%	-	-

Passenger gap injury rates per 100 million passenger-miles and per 100 million passengers carried were calculated and shown in Table 2. The gap injury rates were calculated as follows:

Passenger Gap Injury Rate = Number of gap injuries x 100,000,000/passenger miles

Passenger Gap Injury Rate = Number of gap injuries x 100,000,000/passengers carried

Table 2 also includes FRA passenger-cases rate which includes the frequency of passenger cases per 100,000,000 passenger miles. Passenger cases include all circumstances; including getting off/on standing trains, stumbling aboard trains, assaults, train accidents, crossing incidents and other cases.

Table 2 shows a 95 percent increase in passenger gap injury rate per passenger-mile from 2005 to 2006 compared to an increase of 11percent in the FRA passenger-cases rate for the same time period. From 2006 to 2007 there was an increase in the passenger gap injury rate per passenger-mile of 3 percent compared to a decrease of 20 percent in the FRA passenger-cases rate. In 2008 there was a decrease of 36 percent in the passenger gap injury rate per passenger-mile compared to a decrease of about 40 percent in the FRA passenger-cases rate. The data shows that gap injuries rose at a higher rate than the FRA passenger-cases rate from 2005 to 2007. In 2008, gap injury rates decreased at about the same rate as all reportable passenger injuries.

Table 2. NJ TRANSIT Rail Passenger Gap Injury Rates

Year	Passenger Miles	Passengers Carried	Total Gap Injuries[1]	Gap Injury Rate: Per 100,000,000 passenger miles	Gap Injury Rate: Per 100,000,000 passengers Carried	FRA Passenger Cases Rate[2]
2005	1,762,112,322	67,069,100	38	2.16	56.66	1.42
2006	1,781,346,389	71,000,500	75	4.21	105.63	1.57
2007	1,912,998,965	75,045,800	83	4.34	110.60	1.25
2008	2,098,142,031	77,361,500	58	2.76	74.97	0.76

[1] Source NJ TRANSIT Safety Data [2] Per 100,000,000 passenger miles (Source: FRA, Safety Data, http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/statsSas.aspx)

Time of Injury

Figure 15 shows the percentage of gap and non-gap injuries by time of day. The majority of injuries on NJ TRANSIT Rail, both gap and non-gap injuries, occurred during the AM and PM peak periods with about 63 percent of injuries occurring within these periods. For both gap and non-gap injuries, the highest percentage of injuries occurred during the PM peak period with 37.8 percent of gap injuries occurring between 3 and 7 pm and 34.3 percent of non-gap injuries occurring within the same time period. Twenty-five percent of gap injuries occurred during the AM peak period (7 to 10 AM) and 28.7% of non-gap injuries occurred during the AM peak period. That injuries are higher in the AM and PM Peak periods than at other times reflects passenger volumes and is thus not unexpected. Data on boarding and detraining passenger volumes by time of day could be used to calculate injury rates per passenger by time of day. These gap injury rates would be expected to be lower during the peak period than for other periods given the typical peaking of commuter rail passenger traffic during the peak period.

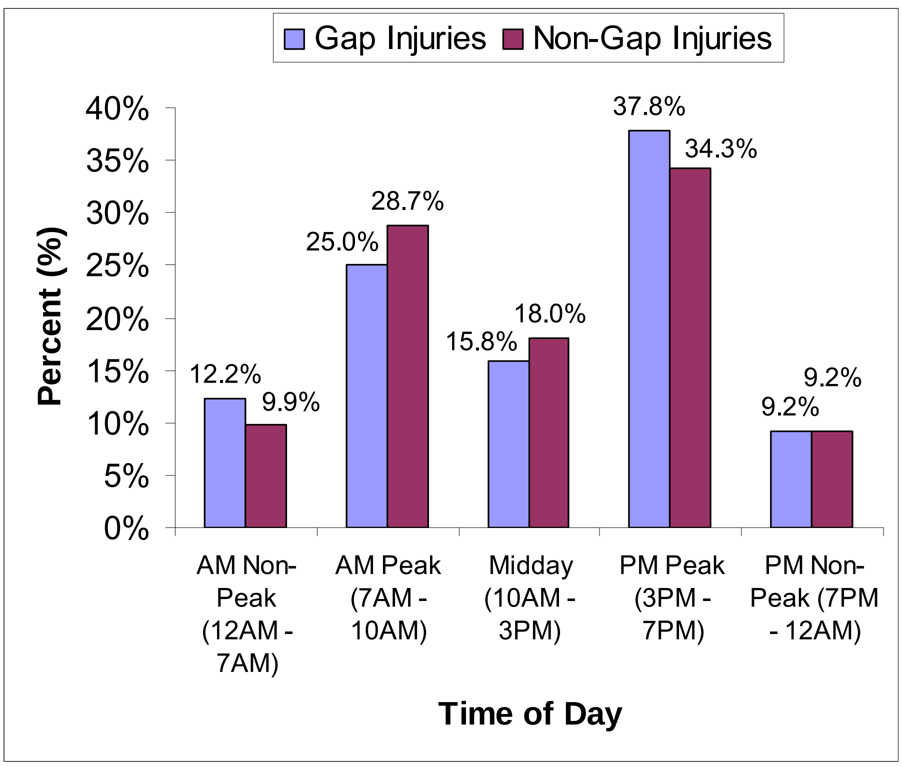

Figure 15. Gap Injuries by Time of Day

Month of Injury

The monthly distribution of gap injuries was determined for gap injuries occurring between 2005 and 2007 and shown in Figure 16. The figure shows differences between the gap and non-gap injuries by month. The highest percentage of gap injuries occurred in October with a percentage of 12.2% of gap injuries, followed by June with 10.7% and December with 10.2%. The highest percentage of non-gap injuries occurred in July with 12.6%.

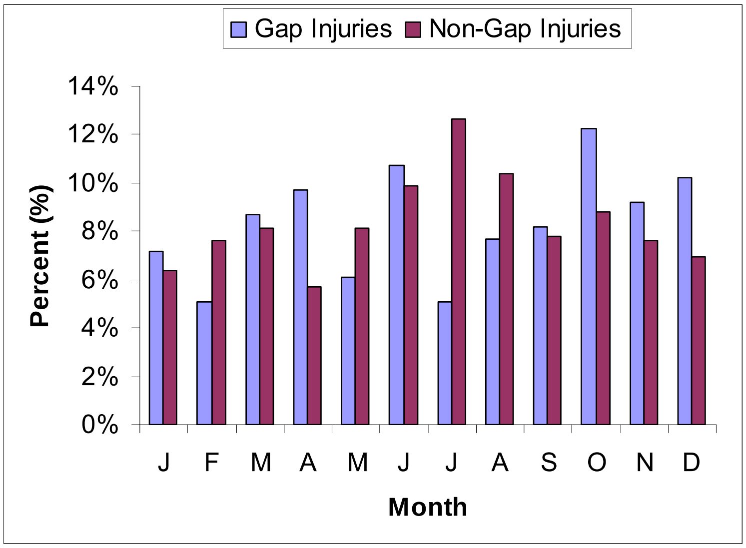

Figure 16. Gap Injuries by Month

Monthly gap injuries were further combined over a three-month period and the distribution of gap injuries determined and shown in Figure 17. The highest percentage of gap injuries occurred during the October to December period with 31.6% of gap injuries occurring within these months. The highest percentage of non-gap injuries occurred during July to September with 30.8% of non-gap injuries. The data showed differences in the percentage distribution of gap and non-gap injuries by month. This difference suggests gap injuries have particular characteristics that may be influenced by the month of the injury. Information about variations in passenger volumes**,** lighting, weather, level of distraction and other behavioral factors that change by month would be needed to better understand the specific characteristics that lead to differences in gap and non-gap injuries by month.

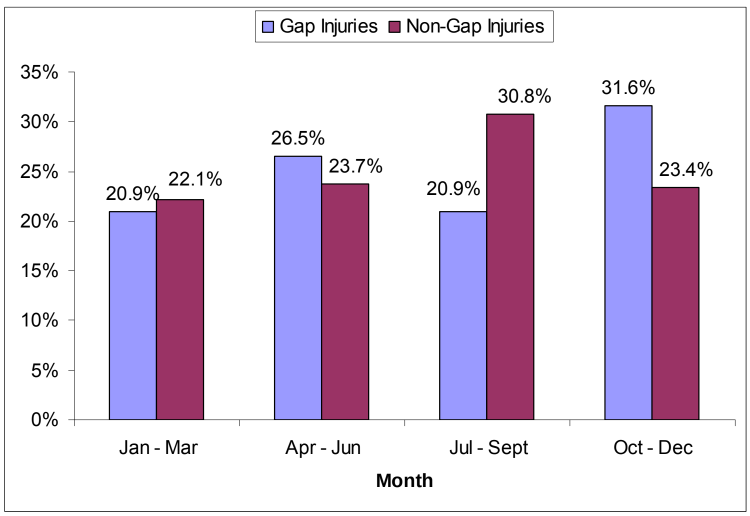

Figure 17. Gap Injuries by Quarter

Relationships between the time of injury and the month of injury were also investigated to determine whether lighting may have some impact on gap injuries. Figure 18 shows the percent of gap injuries occurring within each time period and for each quarter of the year. The figure shows that the peak occurrence of gap injuries is in the AM and PM peak regardless of the quarter of the year that the injury occurs. As previously stated, this is likely due to higher passenger volumes occurring within the peak period. The injury data is not conclusive about the impact of light conditions on the occurrence of gap injuries. Within the AM peak period, gap injuries occurred during the January to March and October to December months with the highest frequency. As daylight is shortest during these months and a portion of the AM peak would occur during dark conditions, lighting may be a factor in some of these gap injuries. During the PM peak period, however, gap injuries occurred with the highest frequency during the July to September months with these months experiencing longer daylight conditions and all of the PM peak period occurring in lighted conditions. Therefore although the data supports lighting as a possible factor contributing to gap injuries during the AM peak period, the data does not support this during the PM peak period. Information about station lighting may provide additional insight into whether light conditions have an impact on gap injuries

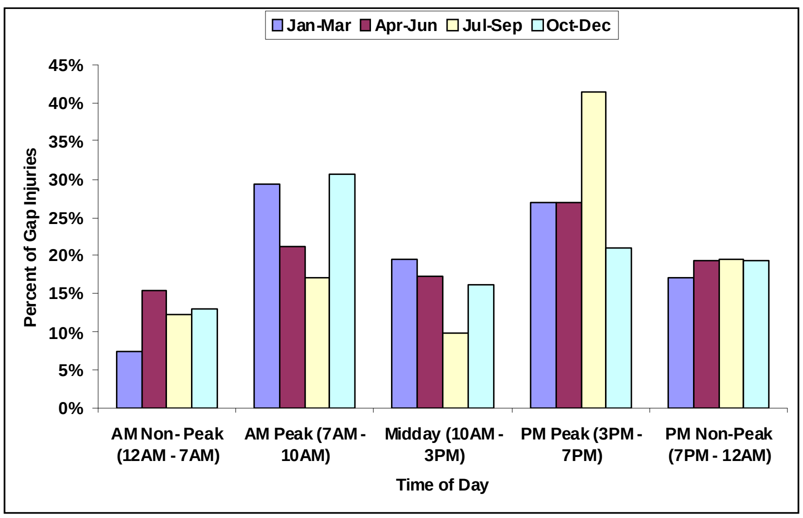

Figure 18. Gap Injuries by Time of Day and Month

Day of Week

Almost 80 percent of gap injuries occurred during the weekday, compared to 86.5% of non-gap injuries that occurred during the weekday. Figure 19 shows the distribution of gap injuries by day of week. The highest percent of gap injuries, or 20.4%, occurred on Wednesdays compared to 17.6% of non-gap injuries occurring on Wednesdays. The lowest percent of gap injuries occur on Mondays with 8.7% compared to 17.6% of non-gap injuries occurring on a Monday. The peaking of gap injuries on Wednesdays may be associated with increased passenger volumes on Wednesdays. However, data on passenger volumes by day of week would be needed to support this conclusion.

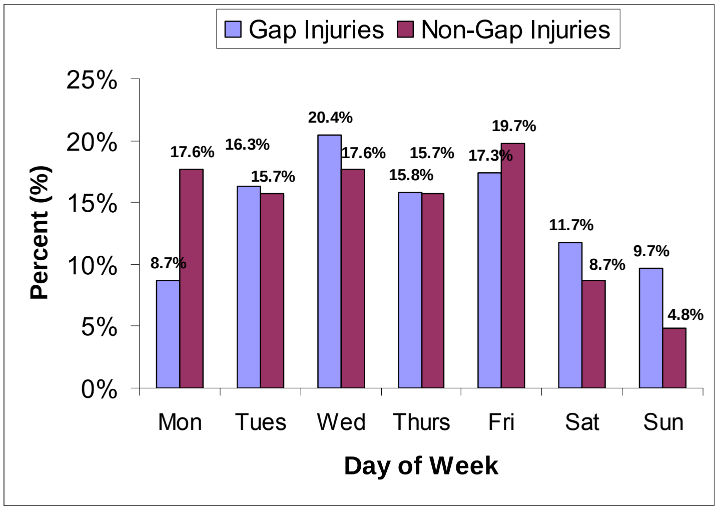

Figure 19. Gap Injury by Day of Week

Table 3 shows the time of day distribution by day of week for gap injuries. The table shows that for each day of the week the highest percentage of gap injuries occurred during the AM and PM peak period. Wednesdays, with the highest percentage of gap injuries, had the highest percent of gap injuries occurring during the PM peak period than any other day. Thirty-one percent of gap injuries on Sundays occurred during the PM peak period as well as during the PM non-peak period.

Table 3. Time of Day by Day of Week for Gap Injuries

Time of Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
AM Non- Peak (12AM - 7AM)	5.3%	17.6%	15.6%	15.0%	6.5%	11.8%	13.0%
AM Peak (7AM - 10AM)	15.8%	41.2%	31.3%	17.5%	25.8%	26.5%	21.7%
Midday (10AM - 3PM)	15.8%	11.8%	21.9%	10.0%	9.7%	20.6%	21.7%
PM Peak (3PM - 7PM)	31.6%	17.6%	21.9%	37.5%	32.3%	26.5%	21.7%
PM Non-Peak (7PM - 12AM)	31.6%	11.8%	9.4%	20.0%	25.8%	14.7%	21.7%

Age of Injured

Figure 20 shows the distribution of the ages of those injured in both gap and non-gap accidents. For gap injuries, the highest percent of injured fell within the age group of 30 and 40 years old with 19.8 percent of gap injuries falling within this age range. For non-gap injuries, the highest percent of injuries occurred for ages between 50 and 60 years old with 24.7 percent of non-gap injuries falling within this age range. The percent of non-gap injuries generally increases as age increases. For gap injuries the percent of injuries peaked for the very young, under 10 years old, then increases with age until the 30-40 year group. After this age group the percent of injuries remains flat for older age groups. The data indicates that unlike non-gap injuries, gap injuries do not increase with age. The very young, under 10 years old, and the middle age, between 30 and 40 years old, have the highest percentage of gap injuries.

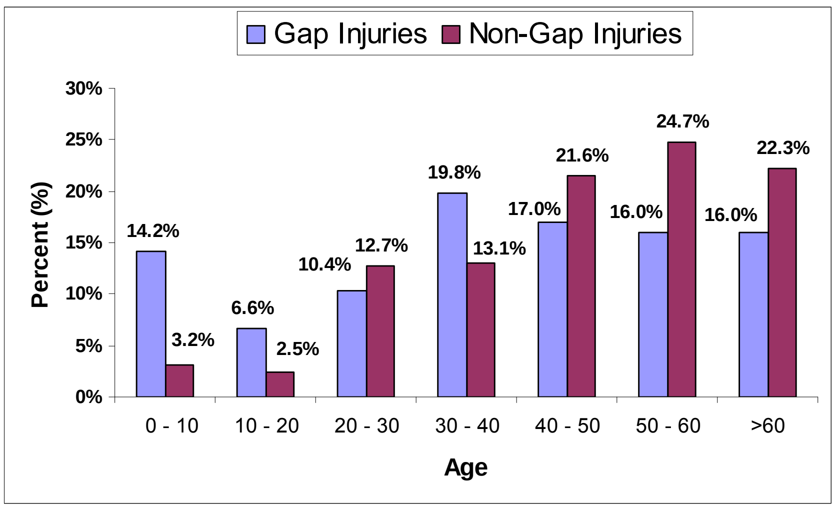

Figure 20. Gap Injuries by Age of Injured

Gap injuries associated with the very young may be attributed to distraction, shorter strides and general unfamiliarity with train boarding and detraining. As shown in Table 4, 40 percent of gap injuries for the very young occurred during the PM Non-peak, 7 pm to 12 am. The high percentage of gap injuries occurring during this time period suggests additional factors associated with late night travel with small children may also impact the occurrence of gap injuries among the very young**.**

Table 4. Gap Injuries by Time of Day and Age

Time Period	0-11 Years Old		30-40 Years Old	
	Frequency	Percent	Frequency	Percent
AM Non- Peak (12AM - 7AM)	0	0.0%	2	8.0%
AM Peak (7AM - 10AM)	2	13.3%	8	32.0%
Midday (10AM - 3PM)	3	20.0%	3	12.0%
PM Peak (3PM - 7PM)	4	26.7%	11	44.0%
PM Non-Peak (7PM - 12AM)	6	40.0%	1	4.0%
Total	**15**	**100.0%**	**25**	**100.0%**

For 30 to 40 year old passengers, the majority of gap injuries occurred during the AM and PM peak periods. Gap injuries associated with 30 to 40 years old may be as a result of higher number of passengers in this age category. Additional data on the passenger ages using NJ TRANSIT Rail would be needed to support this conclusion.

Gender of Injured

For both gap and non-gap injuries, the majority of the injured were women with 69% of gap injuries and 66% of non-gap injuries associated with women passengers. Further analysis was performed to understand differences between gap and non-gap injuries for men and women.

Month of Injury by Gender

Figure 21 compares the percentage of gap injuries by quarter for men and women. As the figure shows, for men there are small differences in the percentage of injuries by quarter with the highest percentage of gap injuries at 27.3 percent occurring during both January to March and October to December quarters. For women, there are larger differences between quarters with the highest percentage of gap injuries at 33.8 percent occurring during the October to December quarter compared to 27.3 percent of injuries for men during the same quarter.

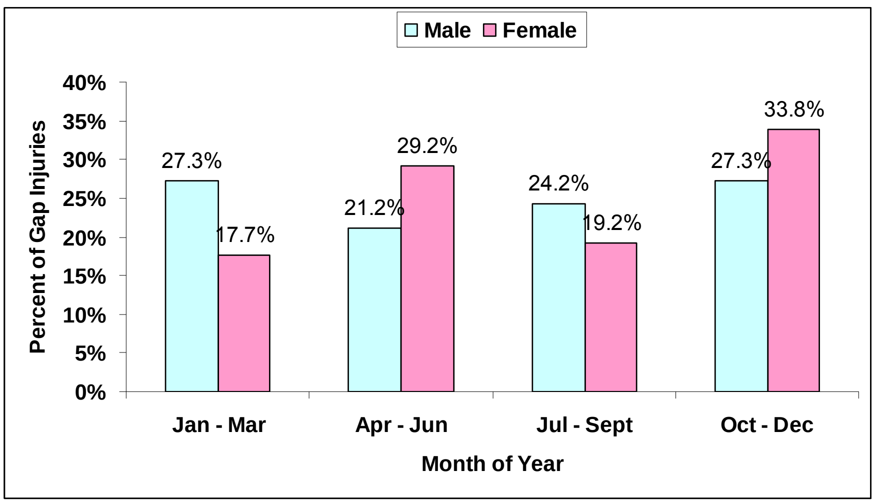

Figure 21. Gap Injuries by Quarter of Year and by Gender

Day of Week

Figure 22 shows the distribution of gap injuries by day of week and by gender. Overall there are similarities in the distribution of gap injuries with the lowest percentage of gap injuries for both men and women occurring on Mondays and Tuesdays. For men the highest percentage of gap injuries occurred on Wednesdays with 22.0% of gap injuries compared to 13.8 percent of gap injuries for women. The highest percentage of gap injuries for women occurred on Thursday with 20.8 percent of gap injuries compared to 18.6 percent of gap injuries for men.

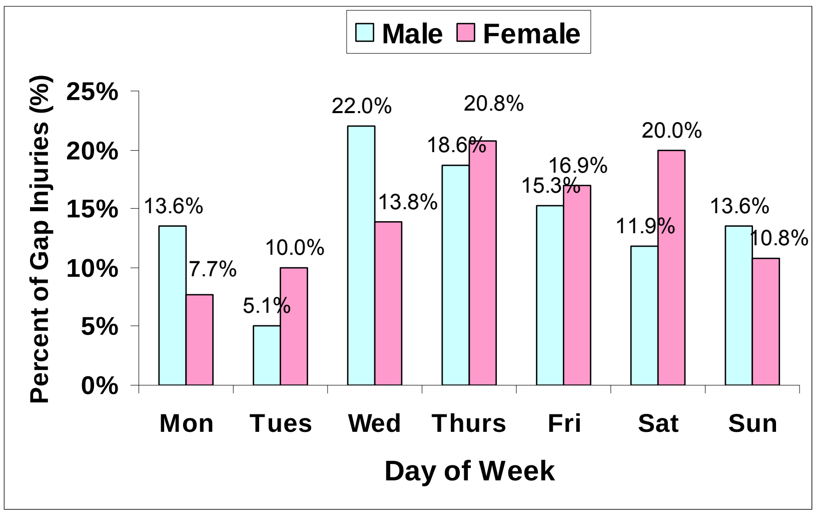

Figure 22. Gap Injuries by Day of Week and by Gender

Time of Day

Figure 23 shows the percentage distribution of gap injuries by time of day and by gender. The figure shows great differences between gap injuries for men and women. For men, gap injuries are distributed throughout the day with the highest percentage (28.8%) of gap injuries occurring during the PM non-peak (7 PM to 12 AM). For women, 63.8 percent of gap injuries occur during the AM and PM peak period compared to 39.4 percent for men. For women, no gap injuries occurred during the AM non-peak period (12 AM to 7 AM).

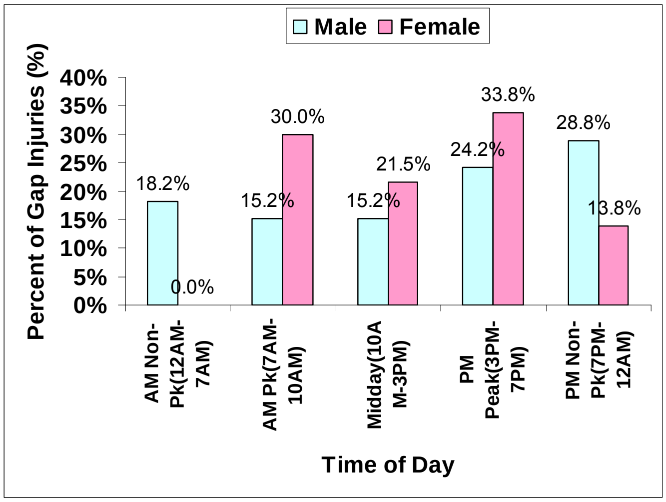

Figure 23. Gap Injuries by Time of Day and Gender

Age of Injured

Figure 24 shows the percentage distribution of gap injuries by age and gender. The figure shows differing distribution of injuries by age for men compared to women. There is a broad distribution of gap injuries for men across all of the age groups with the highest percentage of gap injuries occurring for the under 10 years old with 29 percent of male gap injuries occurring within this age group. The next highest percent of gap injuries for men occurred for the 30 to 40 year old age group with 19.4 percent of gap injuries for men falling within this age group. For women, the majority of gap injuries occur for women 30 years old and higher. The highest percent of gap injuries for women occurred in both the 30 to 40 year old age group and in the 40 to 50 year old age group with 20 percent of gap injuries for women falling within these groups.

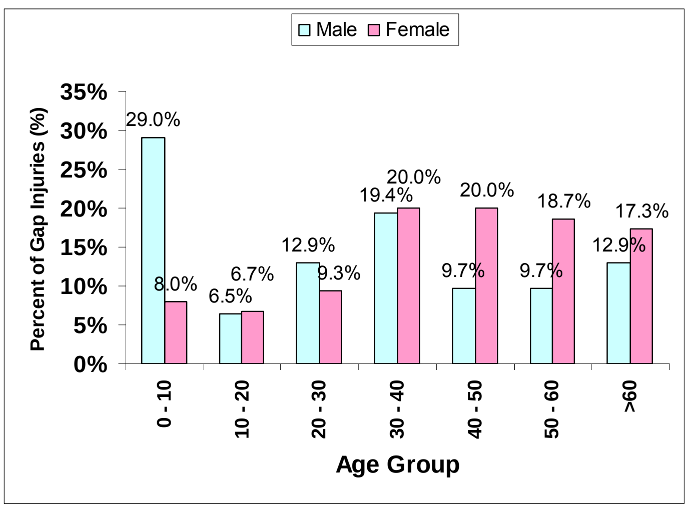

Figure 24. Gap Injuries by Age Group and by Gender

Summary of Gap Analysis by Gender

The analysis of gap injuries by gender shows there are significant differences between gap injuries associated with male and female passengers. Gap injuries associated with women passengers are more likely to occur during October to December, on a Thursday, during either the AM or PM peak period and be associated with women aged 30 to 50 years old. The analysis makes no conclusions on the factors that may contribute to these gap injuries, however, observational studies, described later in the report, may provide some additional insight.

Boarding and Detraining

Sixty-six percent of gap injuries occurred while passengers were boarding. Figure 25 shows the percent of gap injuries by boarding and detraining and by gender. As the figure shows, there is a higher percentage of female passengers involved in gap injuries while boarding compared to male passengers. Seventy percent of gap injuries for female passengers occurred while boarding compared to 56 percent for male passengers.

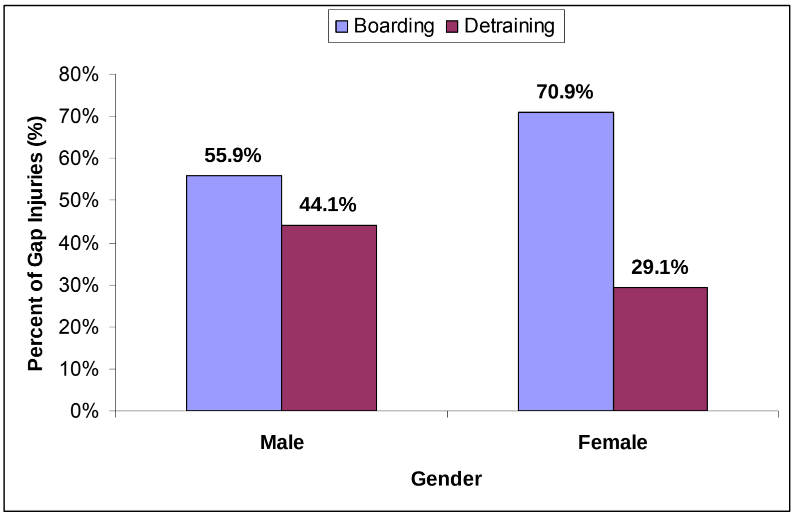

Figure 25. Boarding and Detraining Gap Injuries by Gender

To better understand why females are twice as likely to have a gap injury while boarding, gap injuries by time of day were compared for boarding and detraining passengers and by gender. Figures 26 and 27 show the percent of boarding and detraining injuries, respectively, by time of day and gender. Figure 26 shows that the highest percent (37 percent) of boarding injuries for women occurred during the midday, 10 am to 3 pm, compared to 22 percent of injuries for male gap injuries in the same time period. The highest percent (28 percent) of boarding injuries for men occurred during the PM Non-peak, 7 pm to 12 am. The higher percentage of boarding gap injuries for women during the midday suggest that these injuries are associated with women who are non-commuters and may also be infrequent users of NJ TRANSIT Rail and therefore susceptible to gap injuries.

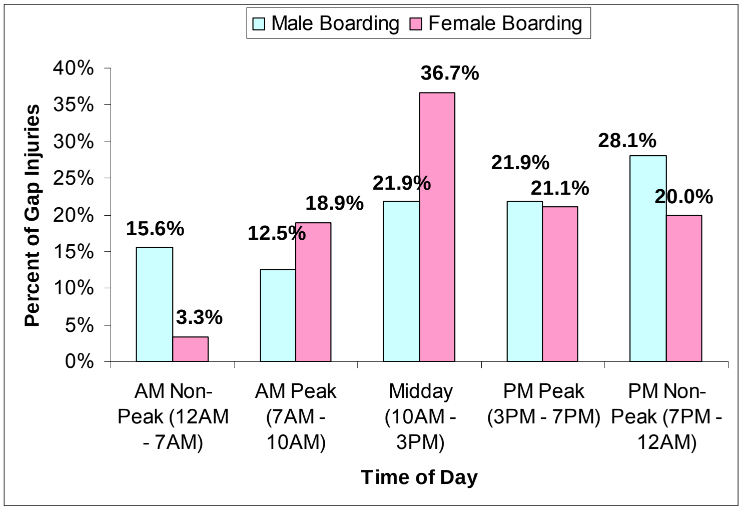

Figure 26. Percent of Boarding Gap Injuries by Time of Day and Gender

Figure 27 shows that the highest percent of detraining injuries occurred during the PM Non-peak, 7 PM to 12 AM, for both male and female passengers.

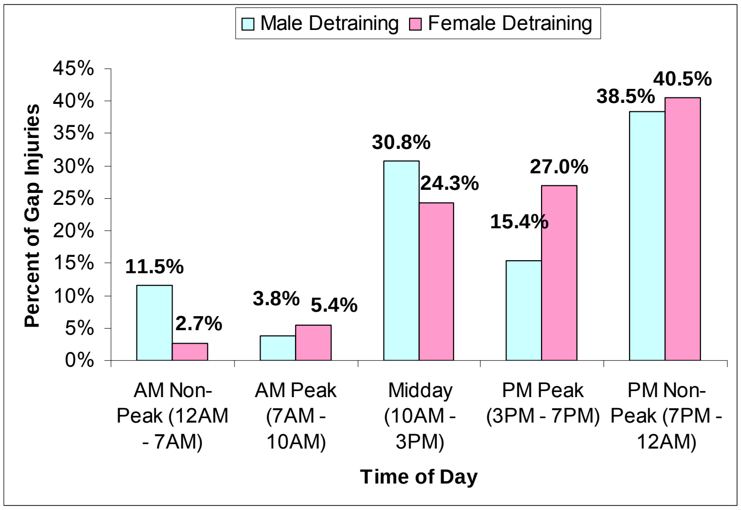

Figure 27. Percent of Detraining Gap Injuries by Time of Day and Gender

Little difference exists in the percent of gap injuries by boarding or detraining during the AM, Midday and PM peak periods, as shown in Figure 28. Differences exist during both the AM and PM non-peak periods. During the AM non-peak there is a much higher percentage of gap injuries for boarding passengers (16 percent) than for detraining passengers (9 percent). During the PM non-peak, there is much higher percentage of gap injuries for detraining passengers (27 percent) than for boarding passengers (15 percent). It would be incorrect to conclude that the higher percent of gap injuries for boarding passengers in the AM and detraining passengers in the PM was due to a higher number of boarding passengers in the AM and detraining passengers in the PM. Each passenger must board and detrain at least once, so the numbers of boardings and detrainings would be roughly equal within the AM period, and the same for other periods. However, the number of boardings and detrainings would be predominantly at different types of stations, i.e., board at suburban stations in the AM while detraining at Newark or Penn Station in the AM, and the reverse in the PM peak.

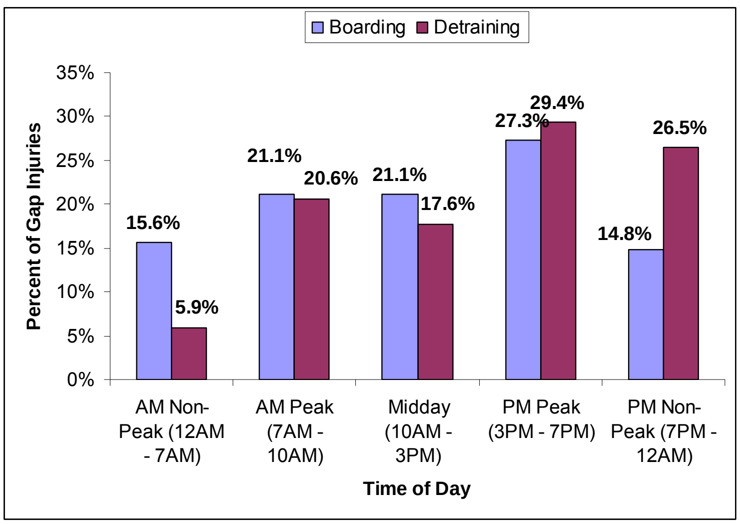

Figure 28. Boarding and Detraining Gap Injuries by Time of Day

Figure 29 shows the gap injuries by boarding and detraining at NJ TRANSIT Rail's suburban stations. The suburban stations include all stations except for New York Penn Station and Newark Penn Station. Gap injuries from Long Branch and Secaucus were also excluded in looking at the suburban stations due to the increased number of transfer passengers at these stations. The figure shows a slightly higher percentage (24 percent) of gap injuries in the AM peak period at suburban stations compared to all NJ TRANSIT Rail stations (21 percent). The largest difference between boarding and detraining at suburban stations compared to all NJ TRANSIT Rail stations is the higher percent of boarding gap injuries occurring during the Midday at suburban stations (35 percent) compared to all NJ TRANSIT Rail stations (21 percent). This higher percentage indicates that gap injuries at these suburban stations may be associated with non-commuters or unfamiliar passengers.

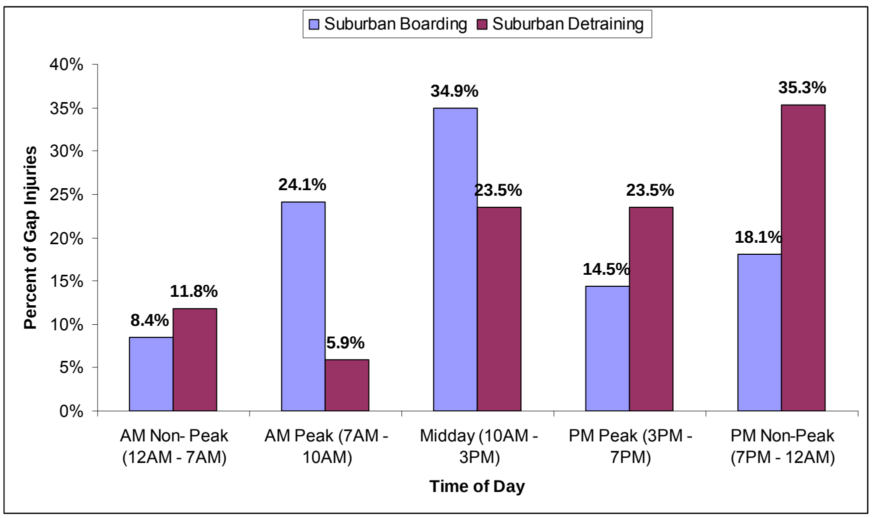

Figure 29. Gap Injuries by Time of Day at Suburban Stations

Figure 30 shows the percent of gap injuries boarding and detraining by age. There are very small differences between the percent of gap injuries boarding and detraining by age for ages greater than 30. The largest differences between boarding and detraining passengers occur for those under 10 years old. Twenty-three percent of gap injuries for detraining passengers fell within this age group compared to 9 percent of gap injuries for boarding passengers. Another age group with significant differences between boarding and detraining gap injuries is in the 20 to 30 year olds where 13 percent of gap injuries for boarding passengers fell within this age group compared to 5 percent of gap injuries for detraining passengers. The study indicates that young children are particularly vulnerable to gap injuries while detraining.

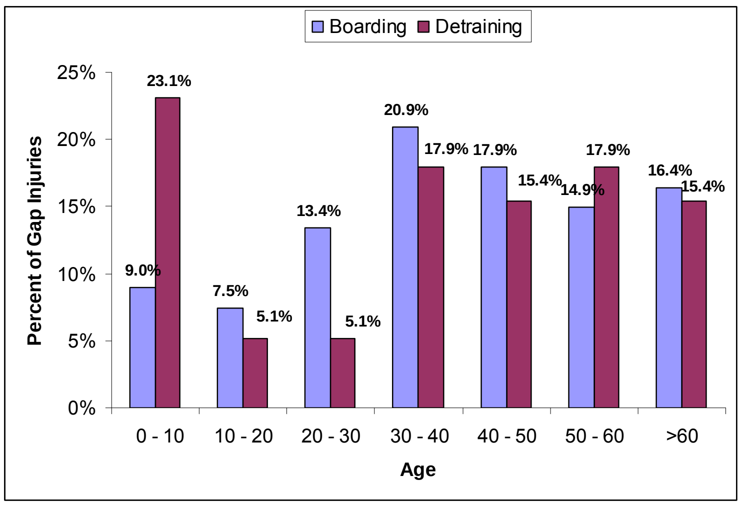

Figure 30. Boarding and Detraining Gap Injuries by Age

NJ TRANSIT Rail Stations with Highest Gap Injuries

Table 5 shows the number of gap injuries at stations with four or more gap injuries from 2005 to 2007. Newark Penn Station and New York Penn Station had the highest number of gap injuries at 28 and 26 gap injuries, respectively. The stations with the highest number of gap injuries are also the stations with the highest number of boarding and detraining passengers.

In addition to showing the stations with the highest gap injuries, Table 5 also shows the percent of gap injuries that occurred during boarding and detraining. For most of the stations, the highest percent of gap injuries occur during boarding. Long Branch and Secaucus Junction were the two stations where the majority of gap injuries occurred during detraining. At Long Branch, 78 percent of gap injuries occurred during detraining and at Secaucus Junction, 63 percent of gap injuries occurred during detraining. As these stations have a high percentage of transferring passengers, it may be concluded that gap injuries during detraining may be associated with transferring passengers.

Table 5. Stations with Highest Gap Injuries for 2005-2007

Station	Number of Gap Injuries	Percent Boarding	Percent Detraining
Newark Penn Station	28	64.3%	35.7%
New York Penn Station	26	73.1%	26.9%
Long Branch	9	22.2%	77.8%
Summit	9	77.8%	22.2%
Edison	8	100.0%	0.0%
Elizabeth	8	75.0%	25.0%
Secaucus Junction	8	37.5%	62.5%
Trenton	8	87.5%	12.5%
Woodbridge	8	75.0%	25.0%
Rahway	7	57.1%	42.9%
Metuchen	6	83.3%	16.7%
Metro Park	5	60.0%	40.0%
Cherry Hill	4	100.0%	0.0%

Gap injury rates per 100,000,000 passenger-miles were calculated for each station and shown in Table 6. Injury rates for transit systems are typically calculated as the number of injuries per passenger miles for the entire rail system. The gap injury rates shown in Table 6 are calculated as the number of gap injuries per station divided the passenger miles for the station. To calculate passenger miles per station would require information on the number of gap injuries per station as well as information on passenger miles associated with each station. To calculate the passenger miles per station, the average weekday rail passenger boarding was used.

Table 6. Gap Injury per 100,000,000 Passenger-Miles by Station

2005			2006			2007		
Station	Count	Rate	Station	Count	Rate	Station	Count	Rate
Cherry Hill	2	111.75	Absecon	2	131.02	Cherry Hill	1	48.52
Long Branch	4	42.80	Elberon	1	86.61	Long Branch	3	31.09
Paterson	1	36.97	Bay St, Montclair	1	62.32	Rahway	6	30.04
Philadelphia, 30th St	1	31.15	Cherry Hill	1	51.97	Broad Street	1	29.35
Atlantic City	2	25.17	Woodbridge	5	46.17	N Elizabeth	1	26.94
Asbury Park	1	23.96	Union	2	33.11	Woodbridge	3	26.56
Plainfield	1	14.64	Ramsey-Rt 17 Station	1	32.76	Philadelphia, 30th St.	1	26.33
Atlantic City Term'l	1	12.59	Hazlet	2	29.48	Lindenwold	1	25.49
Metuchen	3	12.28	Red Bank	3	28.30	Asbury Park	1	23.50
Edison	2	10.23	Summit	5	21.43	Secaucus Junction	4	19.50
Secaucus Junction	1	7.97	Long Branch	2	21.10	Dover	2	19.07
Elizabeth	2	7.37	Secaucus	1	18.63	Edison	4	17.98
Newark Int'l Airport	1	7.24	Secaucus Junction	3	18.39	Roselle Park	1	16.86
Linden	1	7.11	Roselle Park	1	18.08	Glen Rock Boro Hall	1	16.00
Rahway	1	5.40	Plainfield	1	14.64	Trenton	6	14.98
Trenton	2	5.20	Cranford	1	14.34	Elizabeth	4	14.64
Summit	1	4.53	Atlantic City Term	1	12.24	Summit	3	12.33
Hamilton	1	4.30	Edison	2	10.05	Atlantic City	1	11.85
Newark Penn Station	5	3.18	Dover	1	10.01	Newark Broad St.	2	10.89
New Brunswick	1	2.86	Hamilton	2	8.54	Middletown	1	7.53
Metro Park	1	2.23	Metuchen	2	8.19	Newark Penn Station	12	6.84
NY Penn Station	3	0.65	Elizabeth	2	7.77	Westfield	1	6.67
			Newark Int'l Airport	1	7.26	Newark Airport	1	5.45
			Westfield	1	7.10	New Brunswick	2	5.21
			Newark Penn Station	11	6.84	South Orange	1	5.06
			Princeton Jct.	3	6.49	Matawan	1	5.00
			Metro Park	3	6.46	Metuchen	1	3.89
			New Brunswick	1	2.84	Hamilton	1	3.63
			NY Penn Station	13	2.77	Hoboken Terminal	4	3.32
						Princeton Junction	1	2.05
						Metro Park	1	1.98
						NY Penn Station	10	1.97

The average weekday boardings are based on ticket purchases and do not include boardings associated with transfer passengers. As a result, the passenger miles may underestimate the passenger miles at stations with a high number of transfer passengers. The passenger miles per station is determined as:

Pass. miles per station = (Avg. pass. Trip Length) x 260 x (Avg. Wkdy Boarding by station)

The average passenger trip length used for calculating the passenger miles per station was determined using the total passenger miles and passengers carried provided for the entire rail system for each year, as shown in Table 1. Table 6 shows that although the highest number of gap injuries occurred at Newark Penn Station and New York Penn Station, these stations had some of the lowest gap injury rates. In 2005 and 2007, Cherry Hill had the highest gap injury rate with 2 gap injuries in 2005 and 1 gap injury in 2007.

Passenger Observational Surveys

Observations of passengers boarding and detraining were made at stations with a large number of passengers and a high number of gap injuries. The objective of the observations was to categorize behavior and identify factors or conditions that may lead to gap accidents.

Data Collection Locations

Stations with the highest frequency of gap injuries were initially investigated as potential stations for performing the observational survey. The investigation involved performing a gap injury analysis for a select number of these stations using the gap injury data obtained from NJ TRANSIT. The intent of the station gap injury analysis was to determine the time of day, day of week and month when the observational study would be performed. The gap injury analysis by station was performed for New York Penn Station, Newark Penn Station, Secaucus Junction Station and Long Branch Station. The stations for performing the observational survey were finalized through discussions with NJ TRANSIT and after field visits to the stations.

Table 7 shows the dates and times of the observational surveys for each of the study stations. The observational surveys for New York Penn Station, Newark Penn Station and Secaucus Junction Station were performed during the week of August 11th – 15th, 2008 and on November 24th, 2008. The studies were performed during either the AM, Midday or PM peak periods.

Table 7. Observational Study Data Collection Times

Date	Station	Time Period	Notes:
Monday (8/11)	NWK Penn	12:00 PM – 2:00 PM 4:00 PM – 6:00 PM	
Tuesday (8/12)	NWK Penn	8:00 AM – 10:00 AM	
Wednesday (8/13)	Secaucus	8:00 – 10:00 AM	
Thursday (8/14)	NY Penn	9:00 AM - 11:00 AM	Notification of arriving trains was limited. Low volumes entering. Volumes exiting too high to position data collectors to observe.
Monday (11/24)	Long Branch	7:00 AM – 9:00 AM	

Methodology

Using a data collection team of four observers, data were collected at the study stations previously identified. The gap injury analysis determined that 69% of gap injuries were women passengers. For this reason, the observational study sought to distinguish between the behavior of female and male passengers. The methodology taken was to gather data on boarding and detraining passengers at one or more doors of arriving trains. The data gathered included: (1) the number and gender of passengers boarding and detraining; (2) the number of passengers looking down as they boarded or detrained; and (3) the number of passengers with luggage, strollers, holding the hand of a child or using a cell phone. Figure 31 shows the data collection sheets used to perform the data collection.

Track No.	Train Time	Detraining		Boarding		Notes
		1	2	3	4	
	Destination	Total	Female	Total	Female	

Track No.	Train Time	Detraining		Boarding		Notes
		1	2	3	4	
	Destination	Female Looking Down	Male Looking Down	Female Looking Down	Male Looking Down	

Track No.	Train Time	Boarding				Detraining			
		1	2	3	4	1	2	3	4
	Destination	Carrying Luggage	Pushing a Stroller	Holding Child's Hand	Using Cell Phone	Carrying Luggage	Pushing a Stroller	Holding Child's Hand	Using Cell Phone

Figure 31. Data Collection Sheet for Observation Study

The data were collected using 4-button counters with each button used to record the data. Two data collectors were responsible for collecting either the boarding or detraining passengers and whether the passengers, by gender, were looking down. To collect this data accurately required that the data collectors be positioned in a location where they could observe the eye movement of both the boarding and the detraining passengers. Accurate data collection also required moderate volumes entering and exiting when the train arrived. For these reasons terminal stations, such as New York Penn Station, proved problematic for collecting accurate data. At this station, exiting passenger counts were quite high during the peak hour. During the peak hour it was also difficult and hazardous to position data collectors at arriving train doors where the volume exiting the train door as well as the volume on the platform would be very high. Boarding data are also difficult to collect at terminal stations where a train sits at the terminal for some time before departure. In these cases, passengers are free to enter the train at a number of door locations making it difficult for data collectors to anticipate the door from which data would be gathered. For these reasons, the observational data include only a small portion of data from NY Penn Station.

Data Analysis

Table 8 shows the observed number of passengers detraining and boarding. 56 percent of the data collected were for boarding passengers with 44 percent for detraining passengers. Table 9 shows the percent of passengers looking down during boarding and detraining. Over 85 percent of boarding and detaining passengers were observed to be looking down. 78 percent of detraining passengers and 88 percent of boarding passengers were observed to look down. Long Branch was observed to have the lowest percentage of passengers looking down with 55 percent of detraining passengers and 95 percent of boarding passengers looking down. This is consistent with the higher percentage of gap accidents while detraining at Long Branch**.** Secaucus Junction was observed to have the highest percentage of passengers looking down with 82 percent of detraining passengers and 92 percent of boarding passengers looking down. About 76 percent of female passengers and 78 percent of male passengers look down during detraining. For boarding passengers 86 percent of female passengers look down, compared to 90 percent of male passengers.

Table 8. Number of Passengers Observed

Station	Date	Total Detraining	Total Boarding
Newark Penn Station	8/11/2008	150	275
Newark Penn Station	8/12/2008	310	152
Secaucus Junction Station	8/13/2008	17	161
New York Penn Station	8/14/2008	14	50
Long Branch	11/24/2008	40	43
Total		**531**	**681**

Table 9. Percent of Passengers Looking Down

	Detraining Passengers Looking Down			Boarding Passengers Looking Down		
Station	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Newark Penn Station	80.72%	79.59%	80.00%	85.86%	89.41%	87.82%
Secaucus Junction Station	72.73%	83.33%	76.47%	82.28%	92.68%	87.58%
New York Penn Station	75.00%	50.00%	64.29%	88.89%	82.61%	86.00%
Long Branch	42.86%	68.42%	55.00%	95.65%	95.00%	95.35%
Total	**76.21%**	**78.46%**	**77.59%**	**85.94%**	**90.03%**	**88.11%**

In addition to gathering data on the number of passengers looking down at boarding and detraining, data were also gathered on the number of passengers engaged in activities that may be either distracting or "risky behavior" which could increase the potential for gap injuries. Data were collected for four types of distraction: (1) carrying luggage; (2) pushing a stroller; (3) holding a child's hand; and (4) using a cell phone.

Figure 32 shows the frequency of these distractions by boarding and detraining passengers. As the figure shows, of the 1212 passengers observed, the largest type of distraction were passengers carrying luggage. For the stations studied, passengers with luggage were more likely to be boarding than detraining. Prior to performing the study, cell phone usage was believed to be one of the largest distractions to boarding and detraining passengers. The observational studies showed that cell phone usage was not as large as expected. This may be due to the high noise levels on the platform that may make cell phone use impractical.

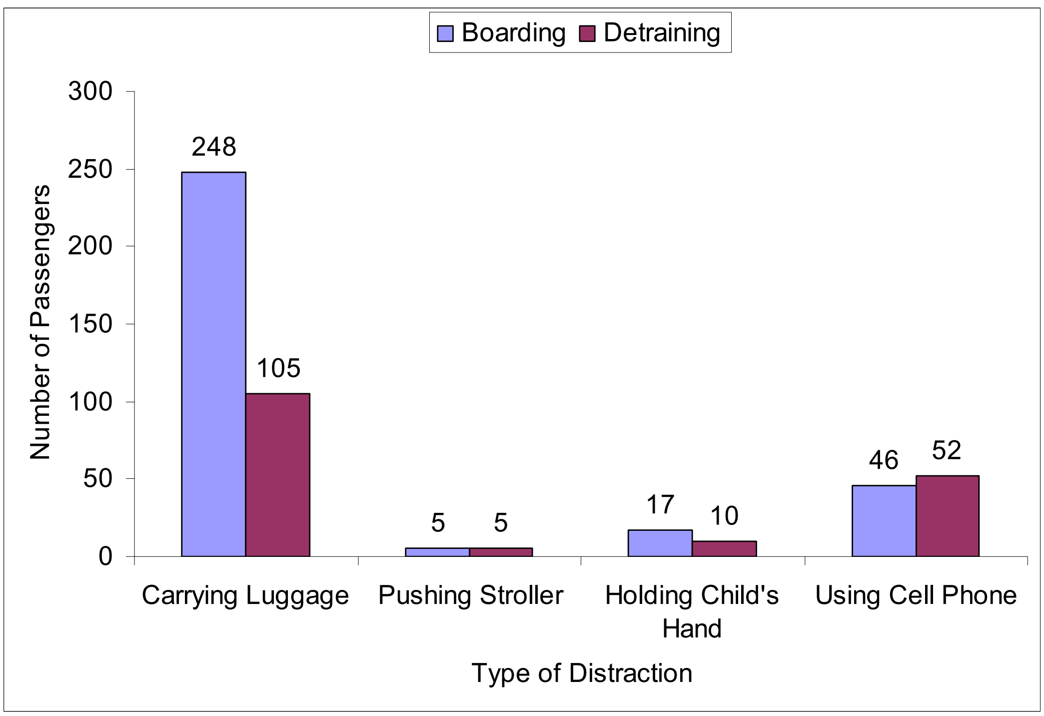

Figure 32. Boarding and Detraining Distractions

STATE OF THE PRACTICE AT LARGE COMMUTER RAILS

Task 4 of the research involved examining the state of practice at other large commuter rails. The intent of the research was to conduct a survey regarding experience with gap-related injuries and what has been done to deal with it at other large commuter rails. Phone calls to Long Island Railroad (LIRR), Metro North, Washington D.C. Metro, proved unsuccessful to capture this information. In addition, calls were also made to Great Britain, with no success in gathering information about what is being done at other rails. In general, the researchers found railroads to be sensitive about providing details about gap injuries at their railroad. At one railroad, the researchers were directed to speak with the railroad's legal department.

What was collected were gap accident data at the LIRR. Figures 33 and 34 show gap accidents per million rides and in total, respectively, from 1996 to 2006 at LIRR.

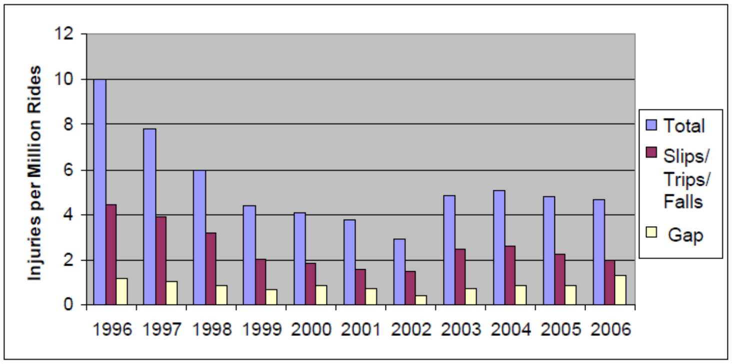

Figure 33. LIRR Customer Accidents per Million Rides (Source: Gap Hearing, 2007)

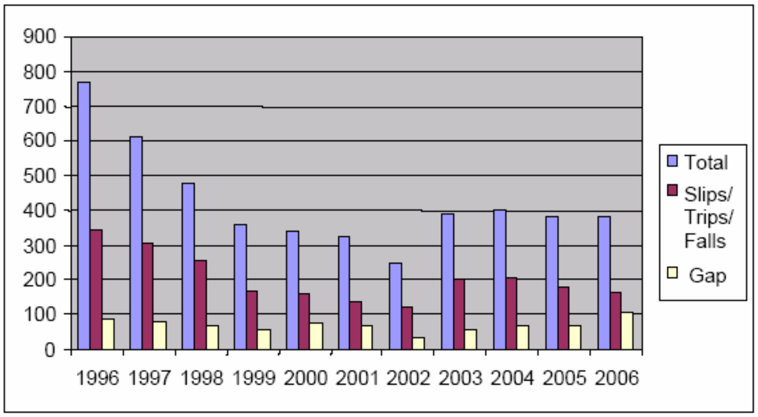

Figure 34. LIRR Customer Accident History (Source: Gap Hearing, 2007)

Platform Lights on the Washington, D.C. Metro

The Washington D.C. Metro uses flashing lights on the platform of train stations to alert hearing-impaired riders that a train is entering the station. The flashing lights are also used by all riders to identify when the next train is arriving. The transit authority recently improved the platform edge lights on station's platforms as part of a six-month pilot program. The authority installed amber LED platform edge lights on the "Yellow" and "Green" line and red LED platform edge lights on the "Red" line platform (see Figure 35). The hope is that customers would take note of the red edge lights and step away from the edge of the platform when an oncoming train is expected.

Each lamp contains 34 LED bulbs and consumes approximately ten watts of power and is estimated to last ten to twelve years. The bulb burns steady at 50 percent power, and flashes at 100 percent power when a train approaches or is at the station. The red and amber LED lamps costs $76 and the traditional white LED lamps cost $108. It takes more than 269,000 bulbs, lamps and tubes and costs up to $11 million a year to light the Metro system, including stations, parking garages, bus garages and rail yards. Metro is currently focusing its stepped up lighting efforts on rail stations, which have more than 73,836 lights.

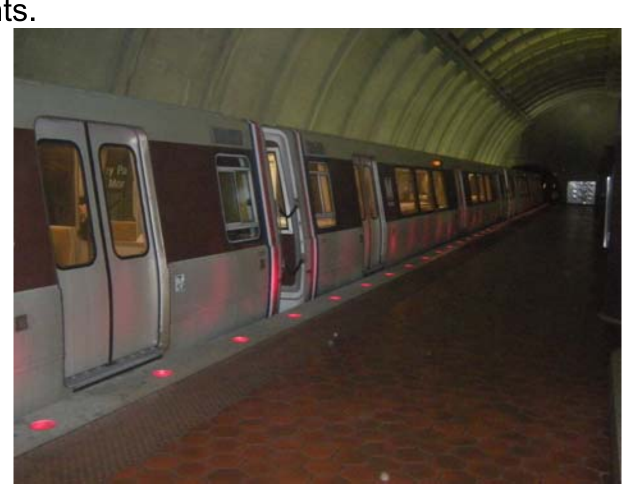

Figure 35. Washington D.C. Platform Edge Lights

Meeting with the Northeast Corridor and MMC Safety Committee Members

To gain additional information from NJ TRANSIT Rail personnel who are involved with safety issues, a member of the research team met with the Northeast Corridor and MMC Safety Committee Members at their regularly scheduled meeting of August 20, 2008. Members were asked about their observations of customer behavior that puts them at risk for accidents when crossing the gap. Most frequently mentioned was rushing for trains. This is particularly the case at Newark Penn Station on the ramp to track 3 & 4. PATH riders come down the ramp in a rush and hold open doors for the train. It was mentioned that the large portions of these passengers have schedules and know when their train is coming. The problem seems to be that when a train is at the station passengers perceive it to be their train even though they know otherwise. There needs to be some way to slow down these passengers coming down the ramp from PATH trains. In addition there needs to be more transit personnel presence to reduce the incidents of holding open train doors.

NJ TRANSIT RAIL EXISTING GAP SIZES

NJ TRANSIT Rail measured existing vertical and horizontal gap sizes at all tracks with high level platforms. Measurements were made at 25 to 100-foot intervals and the measurements taken included the distance from the center line of the track to the platform and the distance from the top of rail to the top of the platform. For each location where measurements were taken, the “Maximum Gap”, “Variance From Side Standard” and “Difference Top of Rail to Top of Platform” were determined. Figure 36 shows the measurements taken and values calculated.

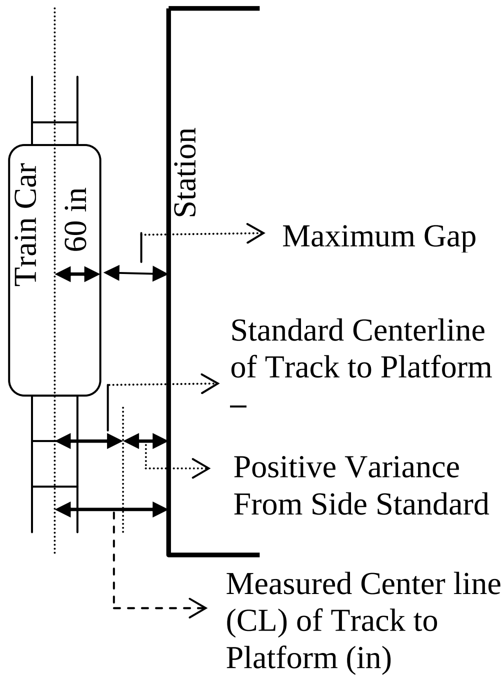

Figure 36. Gap Size Measurement

The maximum gap is calculated as the difference between the measured center line (CL) of track to platform and half of the width of an NJ TRANSIT Rail passenger car or 60 inches. This calculation is performed at each measured location and is calculated as follows:

$$\text{Maximum Gap (in)} = \begin{pmatrix} \text{Measured Center} \\ \text{Line (CL) of Track} \\ \text{to Platform (in)} \end{pmatrix} - (60\text{ in})$$

The maximum gap ranged from 24.45 in. at Princeton Junction (NJT) station to 1.75 in. at New York Penn Station. The excessive gap at Princeton Junction station is associated with the tight track curvature of the Princeton Line, and only affects equipment with center doors. Passengers board and alight only at end doors at Princeton Junction Station. No clear relationships were observed between the maximum gap size at each station and the gap injury frequency or rate. Table 10 shows the maximum gap at each station at the time of this report.

Table 10. Maximum Gap at Each Station

Station	Direction	Track	Track Curve	Superelevation	Location of Measurement (ft)	Measured Center Line of Track to Platform (in)	Standard CL of Track to Platform Edge (in)	Variance from Side STD (in)	Max. Gap (in)	Avg. Gap at Track (in)
Princeton Jct. (NJT)	WE	S	8.87	-1.5	0	76.25	80.30	-4.05	24.45	21.23
Atlantic City	SE	4	5.5		1095	76.00	75.25	0.75	20.98	10.85
NY Penn	WE	17			0	80.00	67.00	13.00	20.00	6.96
Trenton	EE	5			900	80.00	67.00	13.00	20.00	8.19
Gladstone	EE	SINGLE	5.5		0	69.63	75.25	-5.38	14.85	10.13
Newark Broad Street	EE	1	3		31	71.13	71.50	-0.38	13.84	7.88
Montclair University	EE	1	2	0.5	800	71.00	70.00	1.00	12.81	8.44
Newark Penn	WE	3	1.15		1113	71.38	68.73	2.65	12.42	9.57
Summit	EE	WALL	2.875		100	69.13	71.31	-2.19	11.73	8.31
Metro Park	EE	4	0.75	-3.75	400	70.63	68.13	2.50	11.32	10.31
Lindenwold	EE	S	1.42	-1.25	0	69.63	69.13	0.50	10.94	10.59
Absecon	SE	S	1.25	-0.75	50	69.75	68.88	0.88	10.91	10.41
Secaucus Jct. NJT	EE	3		0.25	750	70.88	67.00	3.88	10.88	8.52
Woodbridge	WE	2	1.63	-3	0	69.38	69.44	-0.06	10.88	9.20
Matawan	EE	2	1.5	1	0	69.50	69.25	0.25	10.86	7.76
Elizabeth	WE	1	2	3.25	0	69.00	70.00	-1.00	10.81	7.45
Metuchen	EE	4			400	70.25	67.00	3.25	10.25	9.23
Plainfield	EE	2			400	69.75	67.00	2.75	9.75	8.71
Edison	EE	4	0.5	0.5	400	69.25	67.75	1.50	9.70	9.08
Elberon	EE	1			400	69.50	67.00	2.50	9.50	7.58
New Brunswick	WE	4	0.5	-1.5	700	68.75	67.75	1.00	9.21	7.78
Cranford	EE	2			0	69.00	67.00	2.00	9.00	7.16
Princeton Jct. (AMT)	EE	4			0	69.00	67.00	2.00	9.00	6.09
North Elizabeth	WE	4	0.37	-0.5	200	68.63	67.55	1.08	8.96	7.09
Ramsey RT 17	WE	1			700	68.88	67.00	1.88	8.88	7.91
Rahway	WE	1	0.5	2	0	68.38	67.75	0.63	8.83	7.81

Table 10. Maximum Gap at Each Station

Station	Direction	Track	Track Curve	Superelevation	Location of Measurement (ft)	Measured Center Line of Track to Platform (in)	Standard CL of Track to Platform Edge (in)	Variance from Side STD (in)	Max. Gap (in)	Avg. Gap at Track (in)
Airport	EE	5			300	68.75	67.00	1.75	8.75	6.95
Bay Street	EE	1			500	68.63	67.00	1.63	8.63	7.43
Long Branch	EE	1			200	68.50	67.00	1.50	8.50	7.64
Red Bank	WE	2			300	68.38	67.00	1.38	8.38	7.17
West Field	EE	1			600	68.38	67.00	1.38	8.38	7.72
Dover	EE	2			500	68.25	67.00	1.25	8.25	7.45
Linden	WE	A			0	68.25	67.00	1.25	8.25	6.75
Middletown	EE	2			800	68.25	67.00	1.25	8.25	7.46
Secaucus Jct. AMT.	EE	2			0	68.13	67.00	1.13	8.13	6.40
Hazlet	EE	1			800	68.00	67.00	1.00	8.00	7.42
Mt. Arlington	WE	1			200	68.00	67.00	1.00	8.00	7.48
Paterson	EE	2			0	67.88	67.00	0.88	7.88	6.90
RT 23 Park & Ride	EE	S			175	67.88	67.00	0.88	7.88	7.48
Avenel	EE	2			260	67.75	67.00	0.75	7.75	7.35
Atco	EE	S			0	67.50	67.00	0.50	7.50	7.28
Cherry Hill	EE	S			100	67.50	67.00	0.50	7.50	6.97
Egg Harbor City	EE	S			0	67.50	67.00	0.50	7.50	6.91
Point Pleasant	EE	1			200	67.50	67.00	0.50	7.50	7.05
Asbury	WE	2			200	67.38	67.00	0.38	7.38	6.55
Princeton	EE	S			100	66.75	67.00	-0.25	6.75	6.45
Hamilton	WE	1			900	66.63	67.00	-0.38	6.63	6.31
Hammonton	EE	S			100	66.63	67.00	-0.38	6.63	6.13

About eighty percent of the locations where the maximum gap occurs are within 100 feet of the end of the platform, locations that are typically not utilized to board or alight passengers.

The "Variance From Side Standard" describes the difference between the measured centerline of track and platform and the standard centerline of track to platform edge or:

$$\begin{pmatrix}\text{Variance From Side} \\ \text{Standard (in)}\end{pmatrix} = \begin{pmatrix}\text{Measured Center} \\ \text{line (CL) of Track} \\ \text{to Platform (in)}\end{pmatrix} - \begin{pmatrix}\text{Standard Centerline of} \\ \text{Track to Platform Edge (in)}\end{pmatrix}$$

The standard distance from centerline of track to platform edge is 5 feet 7 inches on tangent (straight) track, which is recommended by the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering. However, this standard distance may increase or decrease depending on the track curvature. Using this standard, the variance ranged from – 10.05 in. at Princeton Junction (NJT) Station to 13.0 in. at New York Penn Station and at the Trenton Station. A negative variance indicates that the centerline of track is closer to the platform than required by the standard. A positive variance indicates that the track centerline is further away than the standard. About 30 percent of the variances are equal to zero, 20 percent are negative and 50 percent are greater than zero. Of those variances greater than zero, the majority of these variances, or 85 percent, are 2.0 inches or less.

Impact of Gap Size on Gap Injuries

An investigation was performed to determine whether there is a relationship between the gap size and the gap injury frequency or rate. Table 11 shows gap injuries by station gap size. The average maximum gap size and variance to side standard were determined for the station.

Table 11. Gap Injury by Gap Size

Station	Average Gap at Station (in)	Average Variance at Station (in)	2005 - 2007 Gap Accident Frequency	2007 Gap Rate[1]
NY Penn	5.98	-1.02	26	1.97
Hammonton	6.13	-0.88	0	0.00
Princeton Jct. (AMT)	6.14	-0.87	1	2.05
Hamilton	6.28	-0.73	4	3.63
Linden	6.35	-0.66	1	0.00
North Elizabeth	6.37	-1.16	1	26.94
Princeton	6.45	-0.55	0	0.00
Airport	6.62	-0.38	1	5.45
Point Pleasant	6.64	-0.37	0	0.00
Asbury	6.69	-0.32	0	0.00
Cranford	6.71	-0.30	1	0.00
Egg Harbor City	6.91	-0.10	0	0.00

Table 11. Gap Injury by Gap Size

Station	Average Gap at Station (in)	Average Variance at Station (in)	2005 - 2007 Gap Accident Frequency	2007 Gap Rate[1]
Secaucus Jct. (AMT)	6.95	-0.05	8	19.50
Cherry Hill	6.97	-0.03	0	0.00
Paterson	7.08	0.08	0	0.00
Hazlet	7.08	0.08	2	0.00
Red Bank	7.08	0.08	3	0.00
Long Branch	7.10	0.10	9	31.09
Bay Street	7.12	0.12	1	0.00
Elizabeth	7.13	-1.60	8	14.64
Avenel	7.17	0.17	0	0.00
Elberon	7.18	0.18	1	0.00
Mt. Arlington	7.19	0.19	0	0.00
Atco	7.28	0.28	0	0.00
Rahway	7.31	-0.68	7	30.04
Summit	7.33	-0.86	9	12.33
New Brunswick	7.43	-0.55	4	5.21
RT 23 Park & Ride	7.48	0.48	0	0.00
Middletown	7.51	0.51	1	7.53
Dover	7.52	0.52	3	19.07
Trenton	7.56	0.34	8	14.98
West Field	7.70	0.70	2	6.67
Secaucus Jct. (NJT)	7.77	0.76	8	19.50
Matawan	7.83	-0.05	1	5.00
Newark Broad Street	7.84	-0.38	0	0.00
Ramsey RT 17	7.86	0.86	1	0.00
Montclair University	8.12	0.35	0	0.00
Plainfield	8.20	1.20	2	0.00
Edison	8.57	0.37	8	17.98
Metuchen	8.78	1.78	6	3.89
Atlantic City	8.99	0.69	3	11.85
Newark Penn	9.03	-1.00	0	0.00
Woodbridge	9.31	-0.12	8	26.56
Metro Park	9.45	0.64	5	1.98
Gladstone	10.13	-3.19	0	0.00
Absecon	10.41	0.48	2	0.00
Lindenwold	10.59	0.16	1	25.49
Princeton Jct. (NJT)	21.23	-7.28	3	0.00

[1] Gap injury rates per 100,000,000 passenger-miles

Figure 37 shows the number of gap injuries from 2005 to 2007 compared to the average gap size. Figure 38 shows the 2007 gap injury rate compared to the average gap size. As shown by the figures, there is no clear relationship between the average gap size at each station and the gap injury frequency or rate. Similar graphs between the gap injury and average maximum gap size and average variance at each station were also determined and no clear relationship between the gap size and gap injury determined.

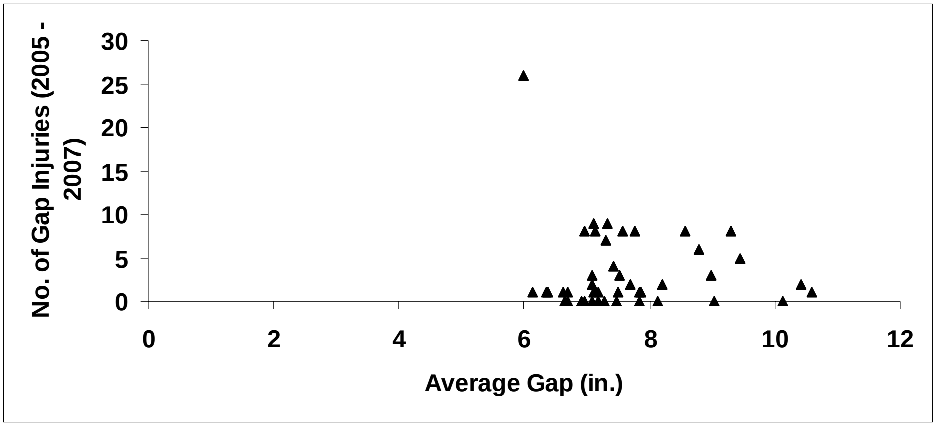

Figure 37. Gap Frequency by Average Gap Size

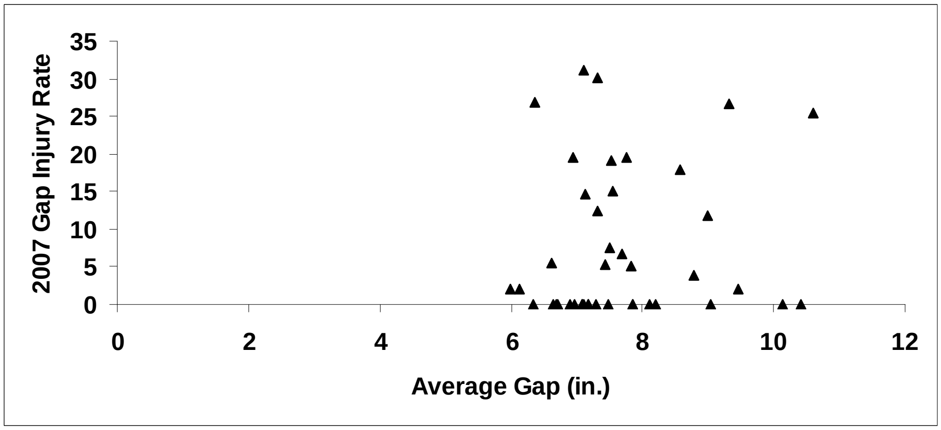

Figure 38. Gap Injury Rate by Average Gap Size

CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this research was to identify factors that contribute to gap accidents on NJ TRANSIT Rail and to make recommendations to reduce these accidents.

Literature Search Summary

The literature search found that while the thrust of analysis of gap problem is one of human factors, no direct behavioral study of passengers crossing the gap were uncovered. Human factor analysis identified demographic issues (age, disability) and behavior issues (rushing, pushing, distractions caused by children, luggage, cell phones) that may contribute to gap accidents at railroads. Platform conditions, including crowding, wetness, size of gap, all contributed to the number and occurrence of gap accidents. Mitigation measures used to treat gap accidents included staff training, public awareness campaigns, staff deployment, dwell times and the use yellow lines.

Summary of Gap Injury Analysis

Overall

An analysis of gap injuries on NJ TRANSIT Rail found that for 2005 to 2008, gap injuries accounted for 25 percent of passenger injuries on NJ TRANSIT Rail. From 2005 to 2006, gap injuries increased by 97 percent to 75 gap injuries compared to a 3 percent increase in non-gap injuries. Between 2006 and 2007 both gap and non-gap injuries increased by 11 percent. Between 2007 and 2008 there was a 30 percent reduction in gap injuries compared to a 10 percent reduction in non-gap injuries. The reduction may be attributed to efforts on the part of NJ TRANSIT Rail to alert passengers to the gap.

Time of Injury

The majority of injuries on NJ TRANSIT Rail, both gap and non-gap injuries occur during the AM and PM peak periods. For both gap and non-gap injuries, the highest percentage of injuries occurred during the PM peak period with 37.8 percent of gap injuries occurring between 3 and 7 pm. A higher percentage of gap injuries in the AM and PM Peak periods than at other times reflects passenger volumes and is thus not unexpected. Data on boarding and detraining passenger volumes by time of day could be used to calculate injury rates per passenger by time of day. These gap injury rates would be expected to be lower during the peak period than for other periods given the typical peaking of commuter rail passenger traffic during the peak period.

Month of Injury

The highest percentage of gap injuries occurred in October, followed by June and December. The highest percentage of non-gap injuries occurred in July. Looking at a three-month period, the highest percentage of gap injuries occurred during October to December. The highest percentage of non-gap injuries occurred during July to September. The data shows differences in the percentage distribution of gap and non-gap injuries by month. This difference suggests gap injuries have particular characteristics that may be influenced by the month of the injury. Information about variations in passenger volumes by month**,** lighting, weather, level of distraction and other behavioral factors that change by month would be needed to better understand the specific characteristics that lead to differences in gap and non-gap injuries by month.

The injury data is not conclusive about the impact of light conditions on the occurrence of gap injuries. Although the data supports lighting as a possible factor contributing to gap injuries during the AM peak period, the data does not support this during the PM peak period. Information about station lighting may provide additional insight into whether light conditions have an impact on gap injuries

Day of Week

Almost 80 percent of gap injuries occur during the weekday, compared to 86.5 percent of non-gap injuries that occur during the weekday. The highest percent of gap injuries occur on Wednesdays. The lowest percent of gap injuries occur on Mondays. The peaking of gap injuries on Wednesdays may be associated with increased passenger volumes on Wednesdays. Data on passenger volumes by day of week would be needed to support this conclusion.

Age of Injured

The highest percent of passengers injured in gap accidents fell within the age group of 30 and 40 years old. For non-gap injuries, the highest percent of injuries occurred for ages between 50 and 60 years old. The percent of non-gap injuries generally increases as age increases. For gap injuries the percent of injuries peaks for the very young, under 10 years old, then increases with age until the 30-40 year group. After this age group the percent of injuries remains flat for older age groups.

The data indicates that unlike non-gap injuries, gap injuries do not increase with age. Gap injuries associated with the very young may be attributed to distraction, shorter strides and general unfamiliarity with train boarding and detraining. Forty percent of gap injuries for the very young occurred during the PM Non-peak, 7 pm to 12 am. The high percentage of gap injuries occurring during this time period suggests additional factors associated with late night travel with small children may also impact the occurrence of gap injuries among the very young. For 30 to 40 year old passengers, the majority of gap injuries occur during the AM and PM peak periods. Gap injuries associated with 30 to 40 years old may be as a result of higher number of passengers in this age category.

Gender of Injured

For both gap and non-gap injuries, the majority of the injured are women. The analysis of gap injuries by gender show there are significant differences between gap injuries associated with male and female passengers. Gap injuries associated with women passengers are more likely to occur during October to December, on a Thursday, during either the AM or PM peak period, and be associated with women aged 30 to 50 years old. The analysis makes no conclusions on the factors that may contribute to these gap injuries, however, observational studies described as a part of this report provides some additional insight.

Boarding and Detraining

Sixty-six percent of gap injuries occurred while passengers are boarding. Seventy percent of gap injuries for female passengers occurred while boarding compared to 56 percent for male passengers. The highest percent of boarding injuries for women occurred during the midday and suggest that these injuries are associated with women who are non-commuters and may also be infrequent users of NJ TRANSIT Rail and therefore susceptible to gap injuries.

There are very small differences between the percent of gap injuries boarding and detraining by age for ages greater than 30. The largest differences between boarding and detraining passengers occurred for those under 10 years old. Another age group with significant differences were the 20 to 30 year olds where 13 percent of gap injuries for boarding passengers fell within this age group compared to 5 percent of gap injuries for detraining passengers. The study indicated that young children are particularly vulnerable to gap injuries while detraining.

During the AM non-peak there is a much higher percentage of gap injuries for boarding passengers than for detraining passengers. During the PM non-peak, there is much higher percentage of gap injuries for detraining passengers than for boarding passengers. Gap injuries by boarding and detraining at NJ TRANSIT Rail's suburban stations showed a slightly higher percentage of gap injuries in the AM peak period at suburban stations compared to all NJ TRANSIT Rail stations. The largest difference between boarding and detraining at suburban stations compared to all NJ TRANSIT Rail's stations is the higher percent of boarding gap injuries occurring during the Midday at suburban stations compared to all NJ TRANSIT Rail stations. This higher percentage indicates that gap injuries at these suburban stations may be associated with non-commuters or unfamiliar passengers.

Stations with Highest Gap Injuries

Newark Penn Station and New York Penn Station had the highest number of gap injuries at 28 and 26 gap injuries, respectively. The stations with the highest number of gap injuries were also the stations with the highest number of boarding and detraining passengers. For most of the stations, the highest percent of gap injuries occurred during boarding. Long Branch and Secaucus Junction were the two stations where the majority of gap injuries occurred during detraining. Although the highest number of gap injuries occurred at Newark Penn Station and New York Penn Station, these stations had some of the lowest gap injury rates.

Summary of Passenger Observational Surveys

78 percent of detraining passengers and 88 percent of boarding passengers were observed to look down while detraining or boarding. Long Branch was observed to have the lowest percentage of passengers looking down with 55 percent of detraining passengers and 95 percent of boarding passengers looking down. Secaucus Junction was observed to have the highest percentage of passengers looking down with 82 percent of detraining passengers and 92 percent of boarding passengers looking down. About 76 percent of female passengers and 78 percent of male passengers looked down during detraining. For boarding passengers 86 percent of female passengers looked down, compared to 90 percent of male passengers.

The largest type of distraction observed were passengers carrying luggage. For the stations studied, passengers with luggage were more likely to be boarding than detraining. Cell phone was not a large distraction as the high noise levels on the platform made cell phone use impractical.

Summary of Gap Sizes

NJ TRANSIT Rail measured existing vertical and horizontal gap sizes at all tracks with high level platforms. From this data, the maximum gaps at NJ TRANSIT Rail stations ranged from 24.45 in. at Princeton Junction (NJT) station to 1.75 in. at New York Penn Station. The excessive gap at Princeton Junction station is associated with the tight track curvature of the Princeton Line, and only affects equipment with center doors. Passengers board and alight only at end doors at Princeton Junction Station. Table 10 shows the maximum gap at each station at the time of this report. About eighty percent of the locations where the maximum gap occurs are within 100 feet of the end of the platform, locations that are typically not utilized to board or alight passengers. The variance from the side standard, or the difference between the measured centerline of track and platform and the standard centerline of track to platform edge, ranged from –10.05 in. at Princeton Junction (NJT) Station to 13.0 in. at New York Penn Station and at the Trenton Station. About 30 percent of the variances are equal to zero, 20 percent are negative and 50 percent are greater than zero. Of those variances greater than zero, the majority of these variances, or 85 percent, are 2.0 inches or less. No clear relationships are observed between the maximum gap size at each station and the gap injury frequency or rate.

Recommendations

Based on the analysis of the data, recommendations on strategies for reducing gap accidents at NJ TRANSIT Rail stations were developed. The recommendations sought to address mitigating factors that contribute to these accidents and are recommended for implementation if feasible and when budget permits.

Passenger Information

The gap injury analysis showed that 66 percent of gap injuries occur while passengers are boarding. Anecdotal information obtained during the observational survey also indicated that passengers are more likely to engage in risky behavior (i.e. running on to a waiting train, rushing off a train when an arriving train comes into view, straddling the train car and platform while gathering information about the train's destination) during boarding and detraining under conditions when they are lacking train information. To address this condition, the following is recommended:

- Use of additional platform personnel during peak periods and at stations with high gap injuries.
- Use of easily viewed platform monitors indicating the train and track numbers, and time of departure. Large signs and consistency in the placement of track number signs.
- Use of pre-recorded messages to "Watch the Gap" that is played while passengers are waiting at the platform and while on the train.

Platform and Train Treatments

The data showed that gap injuries occur at stations with high passenger counts and during the peak periods. This finding indicates that at crowded stations, additional platform and train treatments may be warranted to alert passengers about the gap. Possible treatments include:

- Use of reflective markings at train door thresholds and at locations of the platform with large gaps.
- Use of color to bring attention to existing train hand rails.

- Reduce unusually large gaps where this is feasible given train clearance requirements.

Training

The research team found the NJ TRANSIT Rail train conductors to have a wealth of information about passenger behavior and locations where gap injuries had a greater potential for occurring. The research team, however, believes that additional training can be provided to train conductors by:

- Involving train conductors in the development and deployment of solutions to reduce gap injuries.
- Providing a greater awareness of NJ TRANSIT Rail's current gap injury rates and the target goal for reducing these injuries.
- Alerting conductors to the passenger types and stations where assistance may be needed.

Public Awareness Campaign

The research indicated that women are more likely to be involved in a gap injury and also more likely to not look down while boarding and detraining compared to men. For this reason a targeted public awareness campaign should be developed to address this group.

Costs and Potential Impacts of Recommendations

Relative to redesign of train platforms, the expected costs and potential impact on reducing gap injuries were determined for each recommendation and summarized in Table 12. Recommendations with high impact tend to also be associated with high expected costs and therefore may not be feasible except at critical locations. Although pre-recorded messages are identified as having low impact, the impact may differ by passenger type. The effectiveness of this treatment decreases with use and therefore may not be as effective with commuters and regular users of NJ TRANSIT Rail. The treatment, however, may be very effective for new and infrequent users of the railroad.

Table 12. Expected Cost and Potential Impacts of Recommendations

Recommendation	Expected Cost			Potential Impact on Reducing Gap Injuries		
	Low	Medium	High	Low	Medium	High
Additional platform personnel			√			√
Use of monitors and track number signs		√			√	
Pre-recorded messages	√			√		
Reflective markings on doorways and at locations with large gaps		√			√	
Use of color at train hand rails		√		√		
Reduce large gaps			√		√	
Involvement of train conductors	√				√	
Provide current gap injury rates and targeted goals	√				√	
Alert conductors of potentials for gap injuries	√				√	
Targeted public awareness campaign for women		√			√	

Reducing large gaps is expected to have a high cost. The impact of this recommendation, however, is variable. If it was possible to remove all gaps, no gap injuries would occur resulting in a “high” (rating) impact of this recommendation. If only those gaps considered to be “large” could be eliminated, this would again result in reducing the number of opportunities where passenger gap injuries could occur. Although the data showed no clear relationship between the average gap size at each station and the gap injury frequency or rate, removing opportunities for gap injuries by removing large gaps should result in a “medium” to “high” impact.

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