Railtrack Southern and South West Trains Project American 'PIE'

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RAILTRACK
the heart of the railway

SOUTH WEST TRAINS

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2.0 Abstract

This project, sponsored by Railtrack and South West Trains, addressed platform stepping distances between carriage exits and station platforms, and accidents associated with this problem. A centralized database was created which aided in relating the platform stepping distances to the number of accidents that occurred. Specified stations were ranked according to safety controls and platform stepping distances to identify hazardous platforms. This project was completed with hopes that boarding and alighting from trains will become a safer process.

3.0 Executive Summary

Excessive platform stepping distances are created when a train at a station is not aligned with the platform. These are the cause of numerous personal injuries whilst boarding and alighting from passenger coaches. Railtrack and South West Trains, both based in London, sponsored this project to investigate these safety concerns. Railtrack, the owner of the rail infrastructure in Great Britain, seeks a method of investigating this safety hazard that can be applied to its entirety. The Railtrack Southern Zone was used to investigate the relationship between platform stepping distances and related accidents.

In order to address this issue, platform stepping distances were obtained for the entire Railtrack Southern Zone. This information was paired with accident data for incidents that occurred in the Southern Zone caused by excessive stepping distances. This process determined that there is no apparent relationship between the size of the excessive stepping distances and the number of reported accidents.

The completed project also resulted in a procedure to rank the platforms according to numerous safety factors. The platform stepping distances for each platform were entered into Microsoft Access, along with information obtained from on-site surveys at numerous stations along the Waterloo – Reading route. The platforms surveyed have stepping distances that exceed the current regulations. These on-site surveys examined safety control measures such as warning signs, platform lighting, slip resistant surfaces, warning line, platform surface condition, announcements and obstructions. Each platform was rated based on the type of excessive stepping distances that existed (horizontal, vertical, diagonal) and the quality of the safety controls in place.

Project American 'PIE' has proved to be an educational experience with numerous benefits to both our sponsors and us. It is believed that this project can be used for further assessing the safety associated with each platform. It is hoped that the results of this project will be

disseminated to many individuals and used to resolve the problems associated with boarding and alighting from trains.

4.0 Introduction

Project American 'PIE' was co-sponsored by two rail companies in Great Britain, Railtrack and South West Trains. The first sponsor, Railtrack, owns Britain's national rail infrastructure - its track, signaling, bridges, tunnels, stations and depots. They manage fourteen major railway stations including London-Waterloo, the station at which this project was based. The second sponsor, South West Trains, operates within Railtrack Southern, one of Railtrack's eight regions.

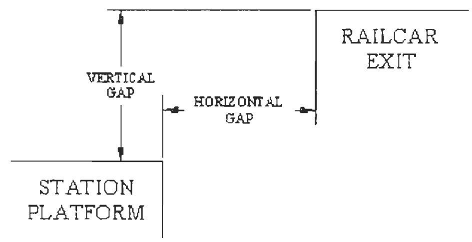

Figure 4.0.1 Diagram of the "gap."

Every day, countless numbers of passengers use the trains as their primary method of transportation. When boarding and alighting from trains at stations, travelers encounter the "gap," the vertical and/or horizontal mismatch between the station platform and the carriage exits. It has been assumed to be the cause of numerous passenger injuries occurring at various stations owned by Railtrack. The "gap" is a major safety concern for both Railtrack and Southwest Trains and needed to be addressed to improve their safety programs.

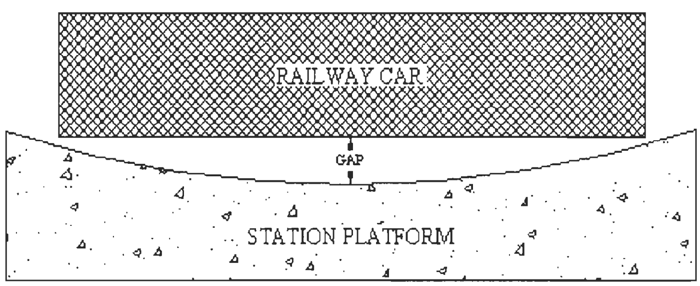

Figure 4.0.2 Carriage and station platform configuration

Railtrack had not been able to undertake an effective risk assessment program regarding platform stepping distances and the safety issues they impose on passengers. This was largely due to the fact that the information concerning passenger safety while boarding and alighting from the trains had not been collected in a systematic manner. Another limitation was that there exists a large number of station platform configurations as well as a large number of carriage configurations, making it difficult to record the size of the "gap" for every combination of carriage and platform.

The main objective for our project was to assist Railtrack Southern and South West Trains in developing a computerized information system for this safety initiative. In order to make this database as complete and accurate as possible, field data were collected at given stations along the Waterloo – Reading line, a train route selected by the sponsors. These data included safety controls at the platforms that had exceedences along the route. The term exceedence is commonly used to designate platform stepping distances that exceed safety regulations. These data, along with platform stepping distance measurements for the C1 – type rolling stock, were compiled into Microsoft Access in order to make the data easily accessible. This database was then used in conjunction with accident data to explore possible relationships between the size of the "gap" and the frequency of passenger injuries reported.

The culmination of this project provided Railtrack Southern with an organized information system and an effective process for analyzing safety issues regarding platform stepping distances. Railtrack Southern and South West Trains were informed which stations along the Waterloo-Reading route have the most serious problems concerning passenger safety related to the "gap." These results may be used internally as a decision making tool for a number of involved Railtrack managers and train and station operators.

The purpose of the Interactive Qualifying Project (IQP) is to enable WPI graduates to understand, as citizens and as professionals, how their careers will affect the larger society to which they belong. The interrelationships between technology and society were examined in such a way as to promote peer interaction. Project American 'PIE' satisfied this requirement because it provided an environment in which we used our technological skills to benefit society. The completed database aided in identifying possible changes to the current railway station designs, which could result in diminished frequency of “gap”-related injuries to rail passengers.

5.0 Background

In order to understand the Platform Incident Evaluation (PIE) problem, several topics were explored. Three different risk assessment methods are discussed and evaluated below. Several terms relevant to risk assessment are also identified and defined. Causal factors, variables that act as catalysts for accidents, are identified to aid in evaluating the relationship between platform stepping distances and injuries. The organization of the passenger rail system in Great Britain and more specifically southern England is provided to convey a sense of the magnitude of the safety problem. Finally, the regional safety standards and regulations associated with the railway are addressed in order to focus on any deficiencies in Railtrack's safety regime.

5.1 Risk Assessment

Risk assessment is a comprehensive term for the many different methods of determining the risk associated with a given system. If risk assessment is to be used effectively, it is necessary to understand its principles and the various methods in which these principles can be applied. Once understood, this knowledge can be used to determine the best method for the assessment of a particular system.

Risk assessment involves the process of determining the possible hazards in a system and calculating the costs and benefits of lowering its risk factor. Risk assessment also attempts to identify and quantify risk so that it can be accurately analyzed, and so that informed decisions can be made based on this analysis. In order to understand this process, it is critical to define some of the terminology associated with risk assessment.

- A hazard is any occurrence that can cause injury, property damage or environmental damage. A hazard is not necessarily the failure of a component or an operator. Firearms, by definition, are hazardous even when they are used properly and they operate correctly (Bahr 7). The "gap" represents a hazard as a result of inadequate design, rather than component or human error.
- Risk may be defined as "the combination of frequency, or probability, and the consequence of a specified hazardous event," but this definition is not comprehensive (Kolluru et al. 13.8). Risk is very subjective, often based upon public perceptions and individual circumstances. For instance, Americans accept the risk of driving a car in spite of the 50,000 highway deaths annually. However, when seven people died from the "Tylenol Killings," public outrage forced the pharmaceutical industry to spend $225 million to improve its packaging (Bahr 204). Public concern about the "gap," the frequency of incidents, and their severity suggest that the risk is real and quantifiable.
- Risk assessment methodology requires that it be applied to a system. The system can be any "interrelation of hardware, software, people, and the operating environment" (Bahr 10). A system may be as complicated as a space shuttle, or in this case as relatively simple as the interaction between carriage, platform, and passenger.
- System safety should not be confused with risk assessment. Risk assessment does not necessarily involve safety and may involve relatively minor risks, such as loss of money or prestige. On the other hand, system safety refers to the process of assuring that a system will not harm people, property, or the environment.

Since its development shortly after World War II, many new methodologies have been created for risk assessment, often tailored to a specific industry or application. The United States Air Force, nuclear industry, and chemical industry have all found or developed methodologies based on their particular needs. Selecting the correct method of risk assessment for a system is critical. Several methodologies common to the transportation industry were examined to determine their relevance to the system in question. Fault tree analysis, probabilistic risk assessment, and hazard analysis are reviewed in the following paragraphs.

Fault Tree Analysis (FTA) is a graphical method of studying a previously identified hazard or fault. FTA allows analysts to identify the various sequences of causes that can lead to a specific hazard event. The relationship of all the factors can be shown, allowing the most important causal factors to be identified.

FTA is most commonly used in the nuclear, aerospace, electronics and mass transit industries. First developed in 1961 for the U.S. military intercontinental missile program, this methodology can be, and has been, applied to many complex systems. It is often used for accident investigation, and was the method NASA used to study the events that triggered the Challenger space shuttle disaster (Bahr 128).

Fault Tree Analysis is most useful for analyzing a specific portion of a larger system. This analysis method therefore does not lend itself well to the "gap" problem, because it is a small system with poorly defined causal factors. In addition, FTA requires expertise and experience not available for this project.

Probabilistic, or Quantitative, Risk Assessment provides a method of quantifying risk in terms of monetary cost. It is based on a quantitative comparison of risks. Hazards are identified using an event tree similar to that used in Fault Tree Analysis. These hazards are then evaluated based on their frequency (probability of occurrence), and the estimated monetary cost of the occurrence. When frequency and cost are multiplied together, they provide the analyst with quantitative values for each hazard.

Probabilistic Risk Assessment is best suited for systems that have well defined hazards and costs. This is very useful in production situations where component failure or human error can lead to unmet quotas and missed deadlines. It can also be applied to large-scale systems like dams and space launches to determine the likelihood and cost of total system failure.

This method has a number of shortcomings when applied to our problem. Due to the lack of data regarding the relative costs of accidents, this methodology cannot be applied. In addition, because the worst outcomes are bodily injury or death, a monetary cost analysis might not be appropriate.

The final method discussed, Hazard Analysis, allows us to identify and evaluate hazards in a method similar to that of Probabilistic Risk Assessment. While hazards are identified in the same manner, their importance is based on a qualitative value. All results of a hazard occurrence are categorized by severity instead of cost. The hazard can then be evaluated according to frequency and severity. Hazard Analysis is a relatively simple method, and may be applied to almost all systems, regardless of their complexity. It is useful in quickly identifying risk and the need for corrective action, if any.

5.2 Causal Factors

The situation in question, namely the "gap" between the railway station platform and the passenger coach exit, was examined to include possible variables that might bring about more instances or greater frequency of an injury. Discussed below are a few of the possible variables that might intensify the overall hazard of the "gap:" weather, passenger mobility, type of rolling stock, safety controls and time of day.

Weather is a factor for platforms located both inside and outside. An outdoor platform is susceptible to many types of precipitation, such as rain, hail, sleet, snow or ice, that could cause slipping or even falling. In the case of indoor platforms, wet shoes and slippery floors could make them potentially dangerous, especially if passengers are not careful.

Passenger mobility is affected by many factors. It is well known that alcohol impairs judgement and mobility. If rail passengers were under the influence of alcohol while traveling, they may be more likely to slip while boarding or alighting from the train. Passenger mobility is also affected by age. Children's strides are not as long as adult's. If their legs cannot cross the "gap," they are at a greater risk for falling and getting hurt. Many elderly people have decreased mobility due to weakening of bones and muscles and are also vulnerable to injury due to their frailty. The same injury sustained by an elderly person might be more debilitating than if a younger person incurred it. Physical disability could also intensify the hazard of the "gap." Individuals who have any sort of physical disability, such as impaired vision, that may hinder movement needed to board or alight from a train safely are at a disadvantage in overcoming the "gap."

On any given route there are many types of rolling stock. Rolling stock is a common term for the various models of passenger coaches used by a train operating company. Since each type of rolling stock has different door and exit configurations, there are various stepping distances to the platform depending on which type is being used.

At each platform there are many safety controls in place. They help passengers by making them more aware of the "gap" when boarding or alighting the carriage. These controls include warning signs, lighting, warning line, announcements, and slip resistant surfaces. The construction of the platform, such as surface condition and physical obstructions, also need to be taken into account when evaluating the severity of each "gap."

The final causal factor that was considered is time of day. There are many times during the day when passenger traffic is heavy and people are in a rush. During these peak times, it is almost certain that one will find pushing and shoving while boarding and alighting. Many times, especially early in the morning and late at night, passengers can be tired and are simply not paying attention to what they are doing. This lack of caution can easily cause an accident on the platform. Although this list is not exhaustive, these factors have been found to be the most suitable according to the current Railway Group Safety Plan.

5.3 Mass Transit by Rail in Great Britain

The role of mass transit in Britain is quite different than in the United States. In Great Britain, a great majority of passenger traffic is by rail, while the United States is much more dependent on private transportation. Understanding the railway network in London and adjacent areas was important to the success of this project.

Railtrack owns and manages Britain's national rail infrastructure, including the track, signaling, bridges, tunnels, stations and depots. It provides access to its track and stations for use by train operators; manages timetabling, train planning and signaling; and maintains the infrastructure. Railtrack owns and runs 20,000 miles of track, 9,000 level crossings, 750 tunnels, 2,500 stations, 40,000 viaducts and bridges. Most stations are leased to the train operating companies (*Figure 5.3.1*), but Railtrack manages these 14 major stations: Birmingham New Street, Edinburgh Waverley, Gatwick Airport, Glasgow Central, Leeds, Manchester Piccadilly and in London: Euston, Liverpool Street, Charing Cross, King's Cross, London Bridge, Paddington, Victoria and Waterloo. Waterloo Station is the home of South West Trains, one of the twenty-five train operating companies that operate under Railtrack (http://www.railtrack.co.uk/corporate/about).

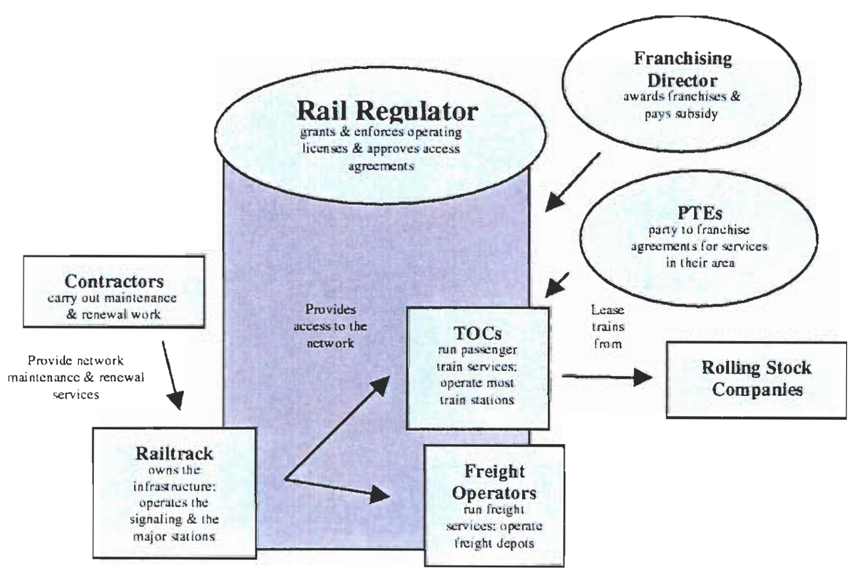

Figure 5.3.1 Railway industry structure diagram (http://www.railtrack.co.uk/atco/index_2.html).

South West Trains runs 1,670 trains every weekday, serving 204 stations and employing approximately 4,000 staff members. Nearly 110 million passenger journeys a year are made on routes through Hampshire, Surrey, Dorset, Wiltshire, Berkshire, Devon, Somerset, East and West Sussex and Greater London, serving a mixture of commuters and longer-distance travelers (http://www.swtrains.co.uk).

5.4 Safety Standards and Regulations

The responsibility for ensuring safety on the railway rests with the train and station operators. Oversight for safety of, and safe working on most of the railway infrastructure in Great Britain is vested in Railtrack. Other offices and issues regarding railway safety and regulation in the United Kingdom are explained in this section.

Ensuring the safety of those in contact with the railway, may it be for travel or work, is a major concern for all involved in the provision and regulation of railway services. There are two main offices which control the safety and regulations in the United Kingdom, the Health and Safety Executive and the Office of the Rail Regulator. The Health and Safety Executive is responsible for the regulation of health and safety on the railway network and this is carried out and regulated specifically by the Inspectorate. The Office of the Rail Regulator is responsible for the licensing of railway activities and regulating the privatized passenger railway (*Figure 5.3.1*). This includes matters such as open access arrangements and promotion of the use and development of the railway network. Safety must be taken into account in all cases where it could become an issue. If there seems to be any doubt when concerning safety implications, the Regulator will consult with the Health and Safety Executive. If the situation needs to be addressed right away, the Regulator can and will use his powers under the licensing procedures to support enforcement actions that are required (White 14).

One branch of the Health and Safety Executive, the HM (Her Majesty's) Railway Inspectorate plays a major role in the safety of passengers and employees of Britain's railways. One of the Inspectorate's duties is to consider, inspect, and approve proposals for new or altered railway hardware. This hardware encompasses any works, plant or equipment that may affect the safe operation of the railway system. Guidance on the standards of construction is needed for the safety of the railway due to the growing railway industry and to the fact that the technology is becoming more complex. The Inspectorate provides this guidance by the self-produced book, *Railway Safety Principles and Guidance.* This book, along with the Inspectorate's advice on the design and construction of new works, is what the approval process is based on. The Inspectorate has powers to investigate accidents and dangerous occurrences, and to inspect the grounds. If need be, notices will be issued where potentially dangerous procedures need to be improved or there are breaches of legislation. The Inspectorate also has the power to monitor accident trends and investigate selected accidents on the railways (http://www.open.gov.uk/hse/railway/rihome.htm).

The Railway Group is defined as "the group of organizations comprising Railtrack and the duty holders of Railway Safety Cases accepted by Railtrack" (Railtrack Railway Group Safety Plan 1999/2000). As of February 1, 1999, the Railway Group comprised of 54 duty holders. The Safety and Standards Directorate exists within the Railway Group. The major role for this department is to provide the focus for safety standards and the best practice throughout the industry. They make sure that the operators are controlling the safety system properly and reducing risks through safety management. Its objective is to help the operators in many ways, such as monitoring hazards and risks across the system. The Directorate acts as the liaison within other organizations worldwide to represent the Railway Group's interest in setting the standards and sharing good practice (Muttram).

The Directorate is organized on a matrix principle, split into five departments of different areas of expertise, headed by the Safety and Standards Director. The five departments include Safety Strategy and Planning, Technical Services, Railway Group Standards, Safety Management Systems, and Industry Safety Liaison. Following is a description of each department.

- The Safety, Strategy and Planning Department's role includes the responsibility for risk modeling and resource planning. It ensures that safety issues are addressed and that improvements are identified and developed.
- The Technical Services Department gives advice to other Departments on specialist engineering and operational matters. It also provides input on safety strategy, Railway Group Standards and other risk controls.
- The Railway Group Standards Department focuses on development and justification of the Standards. These Standards include the controls, together with codes of practice and guidance notes, needed for the railway system safety and safe applications.
- The Safety Management Systems Department ensures that the Railway Group keeps up with changes, both in commercial operations and in technology.
- The last department, The Industry Safety Liaison, deals with external organizations. The central aim is to secure industry-wide support for the management of railway safety (Muttram).

In addition to having these departments, Railtrack develops an annual safety plan each year for the Railway Group. The plan is the end result of a consultation process led by the Railtrack Safety and Standards Directorate. In the plan, they review their progress from the previous year and evaluate their current position. They also state their safety objectives for the upcoming year to improve the existing system. The safety plan reaches a variety of safety issues ranging from passenger and workforce safety to catastrophic risk (http://www.railtrack.co.uk/industry/gsp). Knowledge about the configuration of the railway system and regulations in the United Kingdom helped us assess the present problem by conveying Railtrack's concerns for safety issues. This assisted us in identifying the numerous departments that are affected by the assessment of the "gap" and its relationship to personal injuries. It is hoped that our results appear in the next *Railway Group Annual Safety Plan,* so it will have a positive effect for these safety divisions and on the population of the United Kingdom.

The regulations directly applicable to the project were found in the Railway Safety Principles and Guidance Part 2 Section B: Guidance on Stations. This book was published by HSE (Health & Safety Executive) Books, specifically, the HM Railway Inspectorate in 1996. Regulations applicable to station platforms are as follows. The floor or footboards of passenger rolling stock should be as close as practicable to the platform. The distances between the platform edge and the floor or footboards of the passenger rolling stock should not exceed any of the following dimensions: 250 mm vertically, 275 mm horizontally, and 350 mm on the diagonal. Warning notices reading 'MIND THE GAP' with hatching along the platform edge, or other agreed measures, may be required.

There are a number of control measures or causal factors that also have applicable regulations. On page 7 of the Railway Safety Principles and Guidance, part (f) reads, "All floors, steps, treads etc. should be designed taking into account environmental conditions, contamination and cleaning to minimize the risks of slipping and tripping." There are four guidelines set forth on station and platform lighting, only one of which is applicable to this project. It states, "All station premises to which people have access during the hours of darkness should be adequately lit. Areas to which passengers have access, including foot-bridges, subways, passages, stairways, steps, ramps and escalators, should be permanently lit when there is no daylight."

Principle 11, Stations, deals with making platforms safe for people. It states that "platforms should allow for the safe waiting of people, their boarding and alighting from trains." Factors for consideration should include: (a) the protections arrangements for structural supports against derailment; (b) the compatibility with the trains; (c) the surface alignment in relation to the level of the track and the floor height of the trains; (d) the arrangements to control access to the platforms; (e) the facilities for train crew to observe boarding and alighting passengers; (f) provision for people waiting on the platform and the movement of people on and between platforms; (g) the need to avoid 'pinch points' at platform entrances and exits; (h) the effect of platform edge screen doors on the station and other systems of the railway; (i) the positioning of vending facilities; (j) the arrangements to deter trespass from the platform onto unauthorized parts of the railway; (k) the surface treatment and drainage of platforms to avoid tripping and slipping; (l) the need for platforms to be easily cleaned and the avoidance of places where debris can collect; (m) the aerodynamic effects generated by trains passing through restricted spaces; and (n) ventilation arrangements. Some of these factors will be addressed in assessing the platforms.

6.0 Methodology

The completion of this project was dependent upon the creation of a centralized database in Microsoft Access. Access allows a great deal of information to be organized in a user-friendly manner for our sponsors. The database includes all platform stepping distances for C1-type passenger coaches at all platforms in the Railtrack Southern Zone, and additional information for a limited number of platforms along the Waterloo – Reading route. This information consists of control measures and overall platform rankings.

6.1 Platform Surveys

A list of stepping distances between the station platforms and the footboards of the C1-type passenger coaches for all the stations and platforms in the Railtrack Southern Zone were received from Serco, a Railtrack contractor. Serco had calculated the horizontal, vertical and diagonal platform stepping distance based on previous measurements, and expressed the data in terms of exceedences of current safety regulations. These data were adapted from Microsoft Excel and transferred into Microsoft Access for easier analysis and accessibility. Using these data, platforms along the Waterloo – Reading route that have stepping distances that exceed current safety regulations were identified.

The identified platforms were surveyed for safety controls that included warning signs, lighting, slip resistant surfaces, warning line, platform surface condition, announcements, and platform obstructions. Each control was rated on a 0 – 2 scale before being added to the database (*Table 6.1.1*).

Table 6.1.1 – Safety Control Measurement Scale

Description of control	Points
Control is satisfactory	0
Control needs improvement or repair	1
Control is unsatisfactory	2

The values used for the quality of the safety controls were chosen for the following reasons. If the control measure is satisfactory, it was assigned a value of "zero" (0), therefore decreasing the rank because the safety control was in place. A control that was damaged or in need of repair was assigned a value of "one" (1), thus increasing the rank value for that platform. If the safety control did not exist, it was assigned a value of "two" (2), which again increased the ranking value, more than if the platform needed to be repaired. This system gives a higher ranking to dangerous platforms and a lower ranking to platforms within safety regulations.

6.2 Platform Ranking System

Previously identified platforms along the Waterloo – Reading route were ranked as follows. After initial analysis of the data, a method similar to the Safety Control Measurement Scale was developed (*Table 6.2.1*). The platforms were ranked according to the type of exceedences each one has, based on the information received from Serco. The three types of exceedences are vertical, horizontal, and diagonal. Each type of exceedence the platform possesses was assigned a value of "two" (2). For example, if the information shows that the platform has only one type of exceedence it was assigned a ranking of "two" (2). If it has two types, it was assigned a "four" (4); and if the platform has all three types, it was assigned a value of "six" (6). This system assigns a higher rank to platforms that violate more safety regulations and a lower rank to the platforms within the regulations. The database was designed to add the appropriate exceedence point values to the safety control survey values for an overall platform ranking.

Table 6.2.1 – Exceedence Measurement Scale

Exceedences	Points
One exceedence	2
Two exceedences	4
Three exceedences	6

6.3 Relation of "Gap" Sizes to Accident Data

The other focus of this project was to provide Railtrack with a risk assessment process for the relationship between the frequency and severity of accidents, and the platform stepping distance. After obtaining all of the accident data from Railtrack, it was determined that the method of risk assessment first chosen, Hazard Analysis, could not be used. The initial plans for performing a risk assessment were based on the presumption that a sufficient number of accident reports would be available for individual platforms to determine trends in frequency and severity of accidents. However, the lack of accident reports pertaining to platform stepping distances made these plans impractical.

After consultation with our sponsors, the project was redirected to include the Railtrack Southern Zone instead of limiting it to only the Waterloo – Reading route. This decision was made based on the larger amount of accident data that would be available by including the whole of the Southern Zone. This new direction meant that a method was needed to categorize and compare various rail platforms on the basis of stepping distances, instead of studying individual platforms.

The accident data were retrieved from Railtrack's two incident databases, Safety Management Information System (SMIS) and Delta 5. A great deal of time was spent searching within SMIS for accidents relating to boarding and alighting from trains at stations. SMIS proved to be inadequate for retrieving the data that was needed. After consultation with a Railtrack employee, it was learned that the Delta 5 system contained the information that was needed. The reports of accidents having to do with boarding and alighting from trains at stations were obtained. It was necessary to read all of the reports and eliminate the accidents not related to stepping distances. SMIS was then used to look up each accident to find information that had not been recorded in Delta 5, typically the location of the incident. The incidents recovered were from the entirety of Railtrack Southern and occurred between the years of 1993 to 1999. The information for each incident included the station, platform, date of occurrence, type of accident, and the severity of injury suffered.

The accident information was organized in Microsoft Excel and paired with the platform stepping distance exceedences for the C1 – type passenger coaches at the station where the accident occurred. These data were used to try to find a correlation between the size of the "gap" and the number of accidents that were reported.

The first step of the analysis was performed by categorizing all accident-related platforms by types of exceedences (None, Vertical Only, Horizontal Only, Diagonal Only, Vertical & Diagonal, Horizontal & Diagonal, or All). Each of these categories was plotted to show its percentage of related accidents. Each category was also graphed to show what percentage of platforms belongs to it. It was assumed that if each type of exceedence had an equal risk to passengers, the percentage of platforms in a given category would be similar to the percentage of accidents related to that category.

The next figure maintained the same exceedence categories, but each category was compared to its accident-per-platform (A/P) value. The A/P value was derived by dividing the total number of platforms in each category by the number of accident reports related to that category. This was done so that the relationship, if any, between types of exceedences and the frequency of reported accidents could be determined. A trend line was fit to establish the presence of a linear relationship.

Initial data suggested that there might be a correlation between the size of the platform exceedence and the frequency of accidents. In order to try to quantify the exceedences, in the next analysis they were categorized according to size. The platform categories consisted of 10 mm increments up to a maximum based on the largest recorded types of exceedences. The maximum categories for vertical, horizontal, and diagonal exceedences were 350 mm, 320 mm, and 270 mm respectively. The platforms were also charted according to their types of exceedence (vertical, horizontal, or diagonal). The exceedence size categories were compared with their A/P values. The final step was to fit a trend line over the resultant graph to determine if a linear relationship existed.

The final analysis sought to establish the relationship between compliant platforms versus non-compliant platforms in terms of the incident reports related to each type. The compliant and non-compliant platforms were plotted as percentages of the total number of platforms in the Railtrack Southern Zone. The accidents were separated into two categories, those that occurred on compliant platforms, and those that occurred on non-compliant platforms. These categories were plotted as percentages of the total number of reported accidents.

7.0 Analysis and Results

The creation of the centralized database was an essential part of this project. Created in Microsoft Access, it enabled an analysis of platform stepping distances to be performed. The values for the platform surveys were added so that the platforms could be ranked. It allowed the platforms to be organized in such a way that facilitated the comparison of platform stepping distances in relation to accident data.

7.1 Platform Surveys

The first data entered into the database was the information received from Serco. The data had been input into Microsoft Excel by Serco, but was difficult to work with. A Serco employee calculated the data using C1-Type rolling stock dimensions, rail placement, and platform diagrams. The data included station, platform, date of information gathered, Engineers Line Reference (ELR), track geometry (either curved, straight or both), vertical exceedence, vertical approximate length, horizontal exceedence, horizontal approximate length, diagonal exceedence, diagonal approximate length, minimum height above rails and the maximum height above rails. The exceedences are expressed in millimeters and they indicate the amount over the current regulations. No exceedence was indicated by "NE" in the Excel worksheet. This value was changed to "0" in Microsoft Access to enable an easier manipulation of data. Approximate length indicates the length along the platform where the exceedence occurs; this value is in terms of meters. The minimum and maximum height above rails indicates the minimum and maximum height of the platform above the rails, in millimeters.

The C1-type of rolling stock was used when calculating the stepping distances. This passenger coach was used for a number of reasons. The primary reason was because the exits were located all along the length of the carriage. This configuration of exits makes it possible for a passenger to board or alight anywhere along the platform and therefore encounter the worst possible "gap." Also, since this type of rolling stock is one of the largest and oldest carriages still used, it creates the largest stepping distance. Finally, the C1-type was chosen because it is the most common type of passenger coach used in Railtrack Southern.

After transferring the data into Microsoft Access, the data were then used to find the platforms along the Waterloo-Reading route that had exceedences. These are the platforms that were surveyed for safety controls. The safety control data were gathered by visiting each platform along the route and recording the quality of the controls in place.

7.2 Platform Ranking System

The ranking system was chosen because it incorporated a simple process of locating which platforms have the worst combination of exceedences and quality of the safety controls. The rankings for each control and type of exceedence were entered into the database based on the given range of values. Using Microsoft Access, the values assigned to each control were summed with the values for the platform stepping distance exceedences to give the overall rank for each platform. These platforms were then easily sorted in either ascending or descending order by rank. If a platform obtains a high value for its ranking, the platform is thought to have a high risk and should be addressed due to the danger it engenders for passengers. If the ranking value for a given platform is small, it is thought that the risk involved with overcoming the "gap" is low and that it does not necessarily need immediate attention.

This method of ranking platforms according to its risk value resulted in an easy and quick way to identify platforms violating stepping distance regulations and possible safety control violations. The platforms along the Waterloo – Reading route that have exceedences in platform stepping distances are listed according to decreasing rank and can be found on the next page (*Table 7.2.1*).

Table 7.2.1 – Platform Ranking

Station	Platform	Exceedences (mm)			Track Geometry	Ranking
		Vertical	Horizontal	Diagonal		
Barnes Bridge	Down	196	0	150	C	13
Sunnymeads	Up	161	45	171	C	12
Sunnymeads	Down	137	83	211	C	12
Wandsworth Town	1 Down Slow	310	0	240	C	12
Windsor & Eton Riverside	2	29	50	46	C	12
Windsor & Eton Riverside	1	74	17	46	C	12
Staines	Up	177	0	60	C	11
Wandsworth Town	4 Up Slow	214	0	130	C	11
Ascot	3 DPL	290	0	193	C & S	11
Brentford	Up	153	0	61	S	11
Barnes Bridge	Up	66	0	0	C	11
Wraysbury	Down	188	0	99	S	11
Kew Bridge	Up	154	0	61	C	10
Putney	4 Down Slow	221	0	148	S	10
Wraysbury	Up	322	0	228	S	10
St Margarets	1 Up	171	0	103	C & S	10
Brentford	Down	113	0	30	S	10
St Margarets	UPL	148	0	90	C	10
Virginia Water	4 Down Weybridge	198	90	170	C	10
Winnersh	Down	4	0	0	S	10
Winnersh	Up	45	0	0	S	9
Bracknell	Up	10	0	0	C & S	9
Bracknell	Down	49	0	0	C & S	9
Ascot	2 Down	16	0	0	C & S	9
Kew Bridge	Down	128	0	67	C	9
Earley	Down	14	0	0	C	9
Egham	Up	5	0	0	C & S	8
Hounslow	1 Up	109	0	32	S	8
Mortlake	Up	61	0	47	C	8
St Margarets	2 Down	56	0	0	C & S	8
Wandsworth Town	3 Up Fast	6	0	0	C	8
Virginia Water	2 Down Reading	113	0	50	C	8
Twickenham	4 Up	30	0	0	S	8
Mortlake	Down	8	0	0	C	8
Chiswick	1 Up	85	0	0	S	7
Clapham Junction	5 Down Windsor Fast	38	0	10	C & S	7
Clapham Junction	4 Up Windsor Fast	63	0	30	C & S	7
Richmond	Up	69	0	10	C	7
Virginia Water	3 Up Weybridge	0	40	40	C	7
Richmond	Down	32	0	20	C	7
Feltham	Up	49	0	0	S	6
Hounslow	2 Down	61	0	0	S	6
Chiswick	2 Down	91	0	0	S	6
Syon Lane	Down	65	0	0	C & S	6
Syon Lane	Up	55	0	0	C & S	6
Whitton	Up	48	0	0	S	6
Winnersh Triangle	Down	13	0	0	C	6
Clapham Junction	6 Down Windsor Slow	51	0	0	C	5
Virginia Water	1 Up Reading	11	0	0	C	5

7.3 Relation of "Gap" Sizes to Accident Data

The establishment of the relationship between injuries and platform stepping distances was simplified by the use of Microsoft Office applications. The use of Microsoft Excel in conjunction with Microsoft Access enabled the data to be analyzed. Microsoft Access was useful in sorting the data so that the number of platforms that fall into each category for the type of exceedences could be established. The categories used were "None," "Vertical Only," "Horizontal Only," "Diagonal Only," "Horizontal and Diagonal," "Vertical and Diagonal," and "All." These categories indicated the type of platform stepping distance exceedence occurring at platforms. Since all the accident data had been input into Excel, these numbers were paired with the accidents that occurred at platforms of the above types. In order to find an accurate accident rate, it was necessary to calculate the accidents-per-platform (A/P) value and thus normalize the data. If there are more platforms with a certain size "gap" and more accidents occur, the A/P value will allow one to compare the different platform types and the accident rates.

The first figure consists of two series, all platforms in Railtrack Southern Zone and all platforms with reported accidents in the Railtrack Southern Zone (*Figure 7.3.1*). These series are plotted according to the type of exceedences present at a given platform versus the percentages of the total number of stations in the zone and of the total number of reported accidents in the zone. This figure indicates that for six of the seven categories of platforms (None, Vertical Only, Horizontal Only, Diagonal Only, Vertical & Diagonal, and Horizontal & Diagonal), the percentage of the accidents corresponds with the percentage of the platforms within 12%. In the seventh category (All), the percentage of reported accidents which occurred was 23.5% higher than the percentage of platforms in that category. This suggests that there is a significant increase in reported accidents that occur when all three types of exceedences are present.

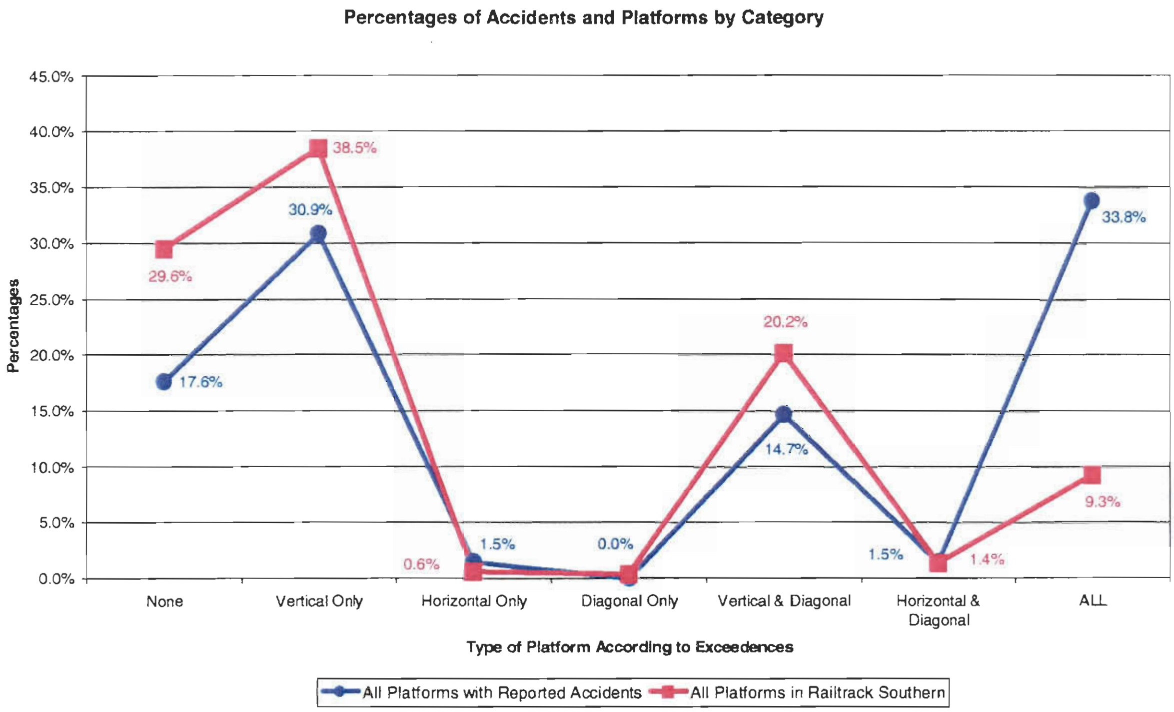

Figure 7.3.1 – Percentages of Accidents and Platforms by Category

The second figure is based on the numbers of accidents-per-platform (A/P) versus the type of exceedences present at a given platform (*Figure 7.3.2*). This figure shows that the A/P rate is highest (0.37 A/P) when all three types of exceedences are present. This reinforces the hypothesis that the largest number of reported accidents occur when all three types of exceedences are present at a given platform. Although the "Horizontal Only" category has the next highest A/P value, it should be noted that there are only 8 platforms in the Railtrack Southern Zone that match these requirements and only 2 accidents were reported as having occurred at those platforms.

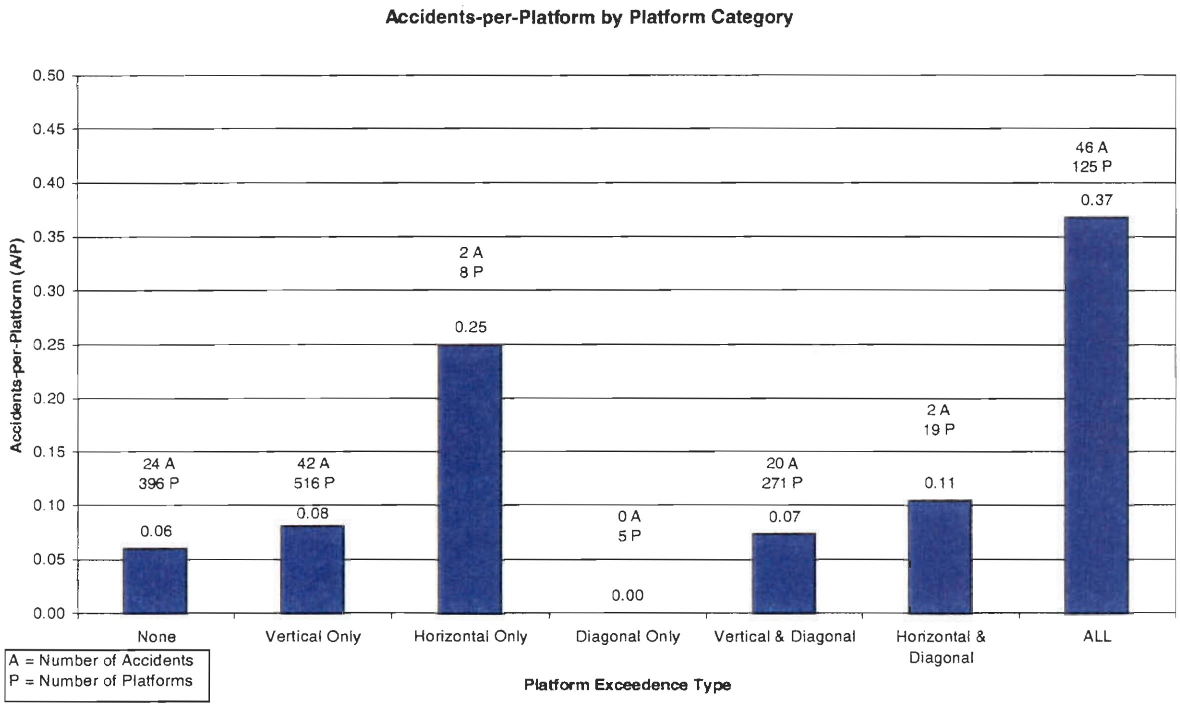

Figure 7.3.2 – Accidents-per-Platform by Platform Category

The next three plots were created in order to try to find a correlation between the size of exceedences (vertical, horizontal or diagonal) and the A/P value. Each figure had the A/P value plotted on the ordinate (vertical axis) and the exceedence of platform stepping distance on the abscissa (horizontal axis). The exceedences were categorized in increments of ten (10) millimeters with one category for no exceedence (0) and from 1 – 10 mm all the way to 341-350 mm (vertical), 311-320 mm (horizontal), and 261-270 mm (diagonal). A trend line was added to the data series with the equation for the line and R, the correlation coefficient. This Microsoft Excel tool performs a linear regression analysis by using the "least squares" method to fit a line through a set of observations.

The correlation coefficient (R) is a measure of the strength of the linear association between two variables. It can range from –1 to +1, with R greater than zero indicating a positive linear relationship; and R less than zero indicating a negative linear relationship. R equal to 0 would indicate no linear relationship.

Correlation establishes the degree of relationship between variables. In this situation, there are two variables, platform stepping distance exceedence and number of accidents-per-platform. Correlation describes how well a given equation describes or explains the relationship between independent and dependent variables. It was hoped that the two variables named above are related to each other such that platform stepping distance exceedence is the independent variable and the number of accidents-per-platform is the dependent variable.

All three figures (*Figure 7.3.3, Figure 7.3.4 and Figure 7.3.5*) indicate that a linear relationship does not exist between the number of accidents-per-platform and the platform stepping distances. This is because the values of R are close to zero, ranging from –0.2577 to –0.1139.

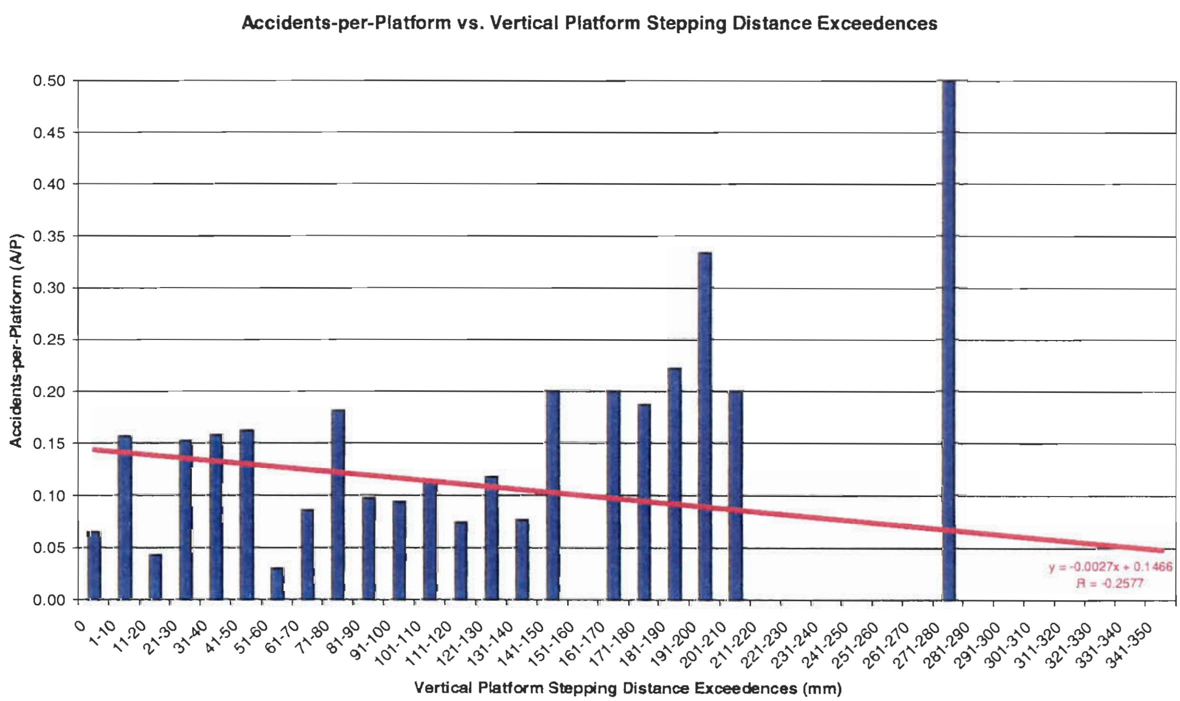

Figure 7.3.3 - Accidents-per-Platform vs. Vertical Platform Stepping Distance Exceedences

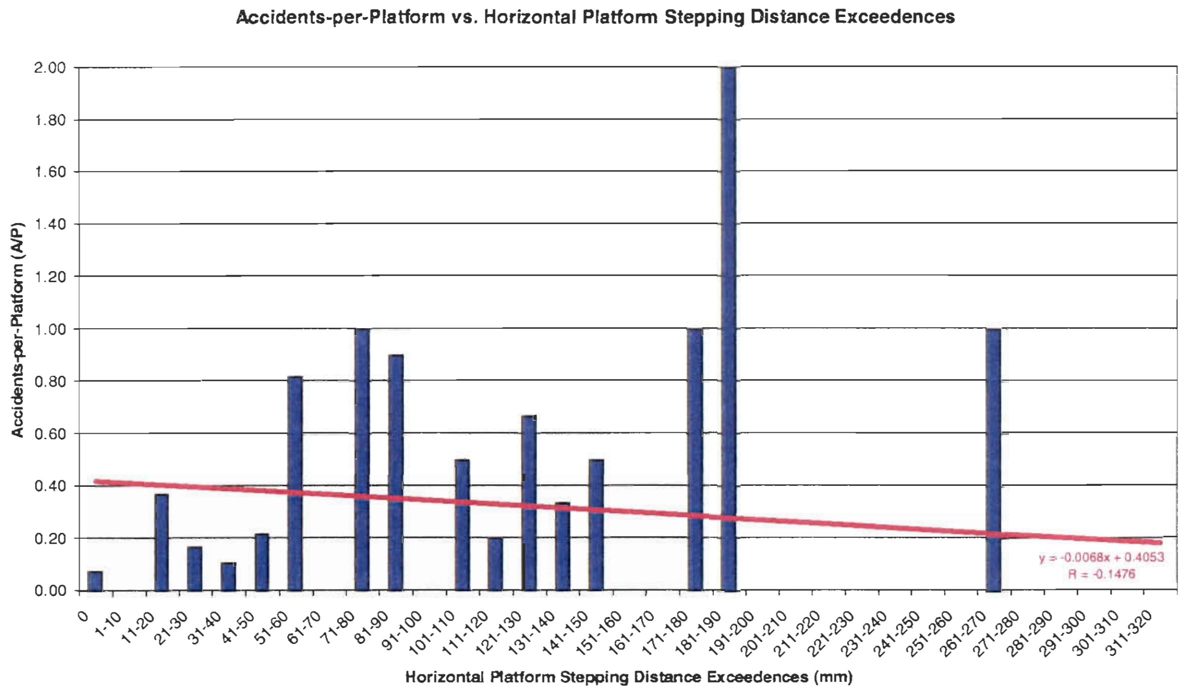

Figure 7.3.4 - Accidents-per-Platform vs. Horizontal Platform Stepping Distance Exceedences

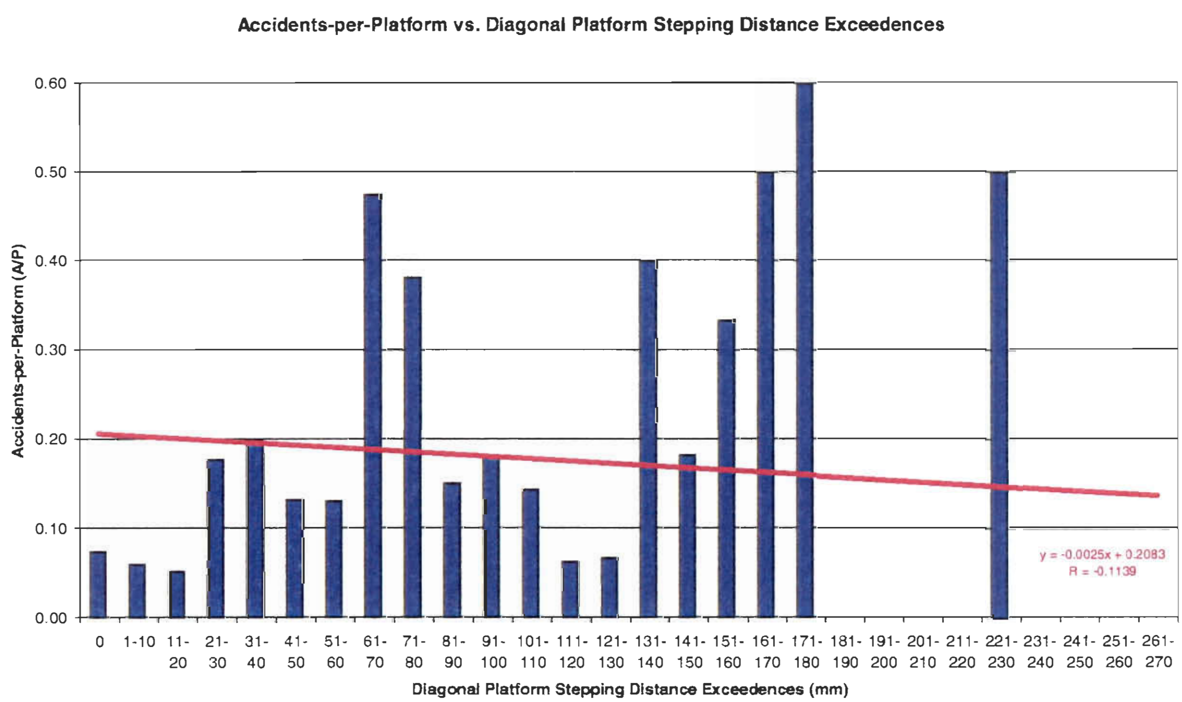

Figure 7.3.5 - Accidents-per-Platform vs. Diagonal Platform Stepping Distance Exceedences

The last plot created shows the relationship between the percentage of accidents that were reported both at platforms with excessive stepping distances and at compliant platforms (*Figure 7.3.6*). Also displayed is the percentage of compliant and non-compliant platforms throughout Railtrack Southern. When these two relationships were plotted on the same axes, it was easy to see the relationship between accidents occurring at platforms with and without exceedences.

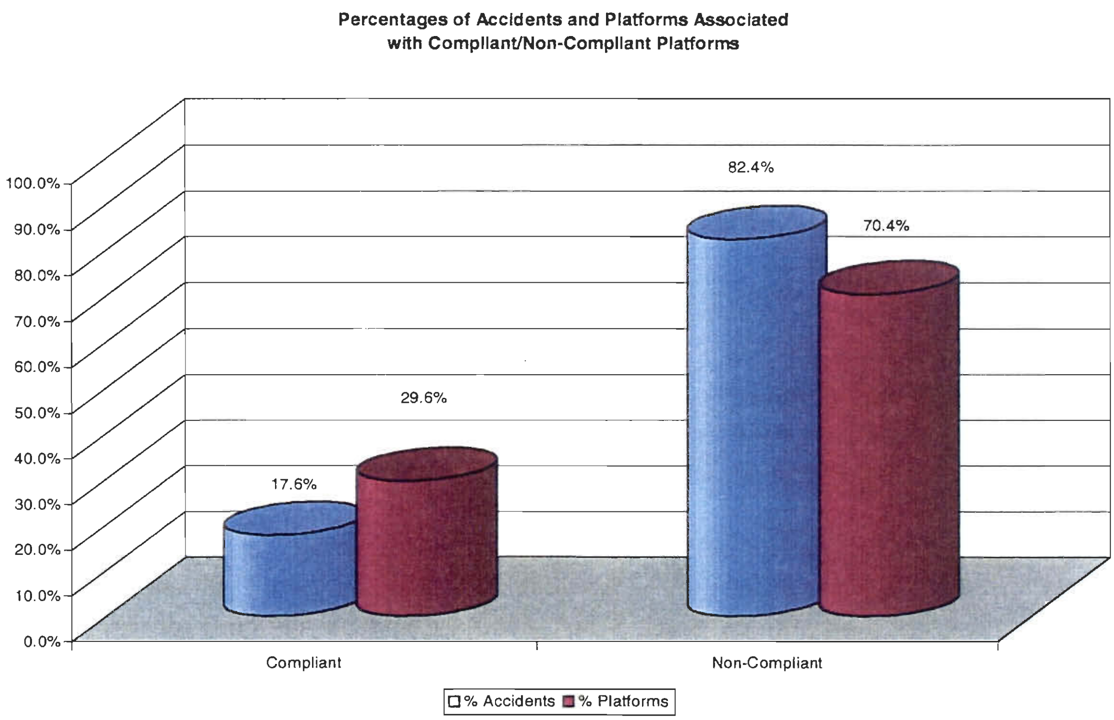

Figure 7.3.6 - Percentages of Accidents and Platforms Associated with Regulation/Non-Regulation Platforms

Based on the aforementioned analysis, it can by hypothesized that the non-compliant platforms are not the cause of the platform incidents. If this were true, then the accidents would have to be spread uniformly across all platforms, independent of exceedence. *Figure 6.2.6* shows that this did not occur. In this case, the percentage of platforms in Railtrack Southern without exceedences was 29.6% and the accidents occurring where there is no exceedence was 17.6%. At platforms in Railtrack Southern, 82.4% of the accidents occurred at non-compliant platforms when 70.4% of the platforms are non-compliant. These data show that a greater percentage of accidents occurred at non-compliant platforms than at compliant platforms. Therefore, the hypothesis is disproved; the non-compliant platforms must be a causal factor of the reported incidents.

8.0 Conclusions

As stated in the methodology, the initial plans for performing a risk assessment were found to be impractical due to the lack of accident reports pertaining to platform stepping distances. In order to perform Hazard Analysis, adequate data must be available to establish the frequency and severity of accidents at any given platform. The number of accident reports available was insufficient and the available ones lacked detail. Although the focus of the project was increased to include the entirety of the Railtrack Southern Zone, the additional information was only enough to study categories of platforms, not individual platforms as initially proposed.

In contrast to the shortage of accident reports, the number of platform stepping distance measurements far exceeded initial expectations. The final form of the database contained these measurements plus safety control survey results from a majority of stations along the Waterloo-Reading route. The database is capable of ranking each platform based on the survey results and its platform stepping distances. It also allows the platforms to be sorted and organized according to any user's preferences.

The analysis of the collected data, discussions with the Railtrack and South West Trains liaisons, and the experiences of the project group have led to the following conclusion. We found that there is no apparent relationship between the platform stepping distance and the reported accidents. This conclusion is based on the fact that after analysis of the available data, little correlation could be found. This conclusion does not imply that non-compliant platforms are equally likely to cause accidents as compliant platforms. In fact, *Figure 7.3.6* suggests that more accidents occur at non-regulation platforms than would be expected. Additionally, *Figures 7.3.1 and 7.3.2* suggest that platforms with three exceedences have a disproportionate number of related accidents, when compared to platforms having none, one, or two exceedences. However, a significant correlation between the size of the exceedences and the occurrence of related accidents could not be established.

Since no apparent correlation was found between the stepping distance and the occurrence of accidents, there must be other factors not addressed in this study contributing to the accidents. Some of the possible factors were addressed in the platform safety control survey described in the methodology; other possible factors, such as infirmity, impaired vision, or alcohol use, were addressed in the Background.

One can only be moderately confident in the results and analysis of the obtained data. Confidence would be higher if the accident reports for the Railtrack Southern Zone were known to be representative of actual circumstances. Discussions with rail employees led to the conclusion that "gap"-related accidents are fairly common occurrences, but few are actually reported. Further discussion with our liaisons confirmed that the compiled accident data did not represent actual circumstances.

The completion of the database and a safety control survey methodology along with the analysis completes the requirement for the IQP. The technical skills used to complete this project will result in a benefit to society if the information is disseminated through our sponsors. The completed database and survey methodology may be useful in conducting further studies in hopes of reducing "gap"-related passenger injuries for Railtrack and its associated train operating companies.

9.0 Recommendations

As a result of this study, several recommendations can be made to alleviate both Railtrack's and South West Trains' problems related to platform stepping distances. The suggested improvements would make it easier for future projects to complete a more extensive study. Recommendations regarding the physical improvements of the platform are also discussed below.

9.1 Reporting of Accidents

If a future study were to be done for Railtrack concerning personal injury, it is necessary that the reporting of accidents to be improved. All future incidents should be reported with more attention to detail, regardless of the seriousness of the injury occurring. More care should be taken to fill out all the possible fields in SMIS, not just the mandatory ones. Data such as severity of injury or more specific information regarding where the incident occurred would have been helpful while completing this project and will be valuable to future studies. Some accident data could not be used in this analysis due to the lack of information regarding cause and location of incident.

A new accident data system may be a useful tool for Railtrack. SMIS is a complicated system to use when searching for a specific type of accident. It was difficult to search for incidents occurring for a specific train operating company or a specific route, even though SMIS appears to have been designed with these types of searches in mind. These searches did not provide accurate results, even when they were successfully completed.

9.2 Completion of "Gap" Measurements

The information received from Serco proved to be very useful to our project. The completion of "gap" calculations in other Railtrack zones would be an equally useful tool for similar future studies. If measurements for other zones existed, a more encompassing study could be undertaken because more data would be available for analysis. Accident data could then be combined with the measurements for the remaining Railtrack zones.

9.3 Completion of Platform Surveys

Due to time constraints, only platforms along the Waterloo-Reading route with excessive platform stepping distances could be surveyed for safety controls. It is recommended that this method of surveying should be applied to all of the platforms in Railtrack Southern. After surveying the platforms for safety controls, the results could then be entered into the database as described in the methodology. A list of rankings for the surveyed platforms would give Railtrack a quick and easy way to locate platforms that need immediate attention. This is outlined in Appendix B, the Standard Operating Procedure for the Evaluation and Rating of Platform Safety Controls.

9.4 Safety Controls

Since redesigning every platform to fit each type of rolling stock within the current safety regulations would not be a practicable solution to alleviate the excessive "gap" problems, other safety measures are suggested. Upon surveying the platforms with excessive stepping distances for safety controls, it was found that there was a lack of both "Mind the Gap" signs and announcements informing passengers to be aware of the "gap." It is recommended that announcements both onboard the train and at the station be used at platforms with excessive stepping distances. This will remind passengers inside the train that there is a "gap," so that injury will not result if they rush to alight or board. "Mind the Gap" signs should be in place wherever there is an exceedence, so passengers waiting for the train are forewarned.

9.5 Hazard Analysis

Although the original proposed method of Hazard Analysis was unable to be utilized due to the lack of accident data, it is still the recommended method to assess the problem associated with platform stepping distances. If accident data were to be reported in the future with more detail as suggested above, a risk assessment could be easily accomplished. The recommended methodology will be included in Appendix C.

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Appendices

Appendix A - Liaison Contact Information

Project American 'PIE' was sponsored by Railtrack Southern and South West Trains. Railtrack Southern is part of Railtrack, a company of approximately 11,000 employees responsible for maintaining and improving most of Britain's railway infrastructure. Railtrack is currently engaged in renovating almost 2,500 stations and depots in Great Britain. Railtrack Southern's liaison for this project is Mr. Chas Blamphin of the Safety & Standards Department.

Our other sponsor, South West Trains, is an industry partner with Railtrack Southern. South West Trains' 4,000 employees manage 1,670 trains every weekday and serve 204 stations in southern England. South West Trains is based out of the London Waterloo Station. The liaison for South West Trains is Mr. Jim Moulson of the Safety and Environment Department.

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Appendix B – Standard Operating Procedure for the Evaluation and Rating of Platform Safety Controls

1.0 This document is a Standard Operating Procedure (SOP) for identifying and evaluating rail platform safety controls. Every safety control listed below may not be required at a given location. Requirements for safety controls are described in Railway Safety Principles and Guidance, Part 2, Section B.

2.0 Each safety control will be assigned a rating based on the listed criteria. Only one rating will be assigned to each safety control.

Rating	Safety Control	Condition
0	Control is satisfactory if:	
	Warning Signs ("Mind the Gap")	• Signs are easily read and highly visible • Signs are frequent throughout length of platform
	Lighting	• Platform is well lit wherever passengers might board or alight trains
	Slip Resistant Surface	• Non-slip surface is present wherever passengers might board or alight trains • Non-slip surface has no smooth areas or visible damage
	Warning Line	• Line is highly visible • Line is present wherever passengers might board or alight trains
	Platform Surface Condition	• Platform is level • Platform has no visible damage that may cause tripping or falling
	Announcements	• Announcements warn of the "gap" • Announcements are frequent and clear
	Obstructions	• Objects on platform to not hinder movement of passengers along platform • Objects on platform to not interfere with boarding or alighting passengers

Rating	Safety Control	Condition
1	Control needs repair or improvement if:	
	Warning Signs ("Mind the Gap")	• Signs are not easily read or require repainting • Signs are not frequent throughout length of platform
	Lighting	• Platform is not well lit wherever passengers might board or alight trains
	Slip Resistant Surface	• Non-slip surface is not present wherever passengers might board or alight trains • Non-slip surface has smooth areas or visible damage
	Warning Line	• Line is not highly visible or requires repainting • Line is not present wherever passengers might board or alight trains
	Platform Surface Condition	• Platform is not level or undulates • Platform has visible damage that may cause tripping or falling (i.e. missing grout or broken pavement)
	Announcements	• Announcements are present, but not frequent and clear
	Obstructions	• Objects on platform hinder movement of passengers along platform • Objects on platform interfere with boarding or alighting passengers

Rating	Safety Control	Condition
2	**Control is not satisfactory if:**	
	Warning Signs ("Mind the Gap")	• Signs are not present
	Lighting	• Platform is not lit
	Slip Resistant Surface	• Non-slip surface is not present
	Warning Line	• Line is not present
	Platform Surface Condition	• Platform has visible damage that may cause tripping or falling (i.e. missing pavement or potholes)
	Announcements	• Announcements are not present
	Obstructions	• Objects on platform greatly interfere with boarding or alighting passengers

Safety Control Checklist

Station ________________________ Platform ________________________

Date __________

Control	Rating
Warning Signs ("Mind the Gap")	_____
Lighting (Platform Fully Lit)	_____
Slip Resistant Surface	_____
Warning Line	_____
Platform Surface Condition	_____
Announcements	_____
Obstructions	_____

Ratings

2 – Control is unsatisfactory

1 – Control needs repair or improvement

0 – Control is satisfactory

Appendix C – Hazard Analysis Methodology

Hazard Analysis Procedure (Barr 74)

Step 1 – Define the System

Define the physical and functional characteristics; understand and evaluate the people, procedures, facilities and equipment, and the environment

Step 2 - Identify the Hazards

Identify hazards and undesired events.

Determine the causes of hazards.

Step 3 - Evaluate the Hazards

Determine hazard severity.

Determine event probability.

Decide whether to accept the risk or eliminate/control hazard.

Step 4 - Resolve the Hazards

Assume the risk, or

Implement corrective action:

- Eliminate
- Control