

# A CASE STUDY ON PLATFORM-TRAIN INTERFACE OCCURRENCES AT A METRORAIL PASSENGER STATION

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## ABSTRACT

Incidents at the Platform-Train Interface (PTI) account for the majority of incidents occurring at train stations in South Africa. The precursors of these incidents are attributed to human behaviour and platform design. One of the main aspects of platform design is the gap size between the train and the platform. Previous research has shown no clear correlation between the gap size and accident occurrence frequency; however, the presence of a large gap creates an opportunity for PTI incidents to occur when coupled with other human behavioural stress factors. An observation survey was carried out at Rissik Station (Pretoria) to determine the influence of the gap size on passenger behaviour. The results of the observations suggested that the gap size did not have an influence on passenger behaviour. However, the study identified that a lack of information dissemination through adequate communication, overcrowding and train design were the three main stress factors that could result in PTI incidents at Rissik station. These stress factors combined with a significant gap size, are believed to result in PTI incidents occurring at train stations.

**Key words:** Human factors, accessibility, platform-train interface, safety, occurrences, incidents.

## 1. INTRODUCTION

### 1.1. Background

International research has indicated that urbanisation will continue to increase at an alarming rate in the future. The current pattern seen in South Africa indicates an increase of 1 million people in Gauteng according to the 2011 census. This increase was due to the migration of people from the Eastern Cape, Northern Cape, Free State, KwaZulu Natal, Limpopo as well as immigrants from Southern Africa. This drastic increase in the urban population could have a crippling effect on the transport system if it is not upgraded to accommodate this growing volume of commuters. Commuter metro rail has proven successful in major urban cities, due to its ability to transport up to 40 000 passengers per hour over distances of up to 90 km. Metrorail, the commuter rail service arm of the Passenger Rail Authority of South Africa (PRASA), is an example of a commuter metro rail system. Metrorail is responsible for transporting approximately 2 million passengers per day nationwide (Metrorail.co.za, 2018).

For many years in South Africa, the government has dedicated minimal resources in support of rail as a preferred mode of transport. This was due to the De Villiers Report (1986) that recommended the restriction of further capital investment in the railways. This lack of political support led to extreme degradation of the Metrorail line, where trains are currently

operating in a substandard mode. The result of operating in this mode leads to unsafe conditions for train commuters. During the 2015/2016 reporting period, the Railway Safety Regulator (RSR) reported 4250 operational occurrences and 5520 security related incidents. The number of fatalities and injuries during the same reporting period totalled 453 and 2290 respectively (RSR, 2015).

Incidents at the PTI account for the majority of incidents occurring at train stations in South Africa, resulting in 37 per cent of passenger related occurrences during the 2015/2016 reporting period. The precursors of these incidents are attributed to human behaviour and platform design. One of the main aspects of platform design is the gap size between the train and the platform. According to the Platform train interface strategy, published by the Railway Safety and Standards Board (RSSB) in 2015, a gap size of 75 mm (horizontal) and  $\pm 50$  mm (vertical) is considered safe for commuters and enables unassisted accessibility for Persons with Reduced Mobility (PRMs). In South Africa many passenger train stations share the same track as freight trains thus making it unsafe to design stations that have a horizontal gap clearance less than 100 mm wide. Due to this limitation, PTI incident mitigation cannot be limited to platform design; human factors must be incorporated in the research to find the optimal solution to eliminating PTI incidents at train stations. Consequently, a study was conducted at Rissik station in Pretoria to observe passenger behaviour in relation to the gap size and other possible stress factors.

## **1.2. Objective of the study**

The objective of this study was to identify the stress factors at train stations that may contribute to PTI incidents.

## **1.3. Methodology**

The following methodology was followed:

1. Measurement of the horizontal and vertical gap between the train and the platform
2. An observation survey conducted to record passenger behaviour in relation to the gap size.
3. Identification of other stress factors that may result in PTI incidents.

## **2. SUMMARY OF LITERATURE REVIEW**

### **2.1. Overview**

Research on platform design, which focused on Metrorail was conducted in 2017. Metrorail was selected as the focus of the research due to the large number of PTI occurrences reported (by the RSR) at train stations under PRASA's operational authority.

The following chapter explores literature on how human factors influence passenger safety in train stations, novel methods of monitoring the gap size in train stations and possible methods of quantifying the cost (direct and indirect) of PTI incidents.

The literature also explores the concept of train schedule reliability. Research has shown that train schedule reliability and information dissemination have a significant influence on passenger behaviour, which in turn, influences safety in train stations.

## **2.2. Average gap size vs. gap injury frequency**

Research has shown that majority of incidents documented have been as a result of human factors and not rolling stock or train operations (NJDOT, 2009). It has been suggested that focusing on passenger characteristics as opposed to changing the platform design would be more efficient in reducing PTI incidents (NJDOT, 2009).

According to the New Jersey Department of Transport (NJDOT) (2009), no correlation was found between the average gap size and the gap injury frequency. A similar study was conducted by the Railway Safety regulator of South Africa (2014), where a slight correlation between gap size and PTI incidents was observed. The study revealed that a vertical gap size of 400 mm or larger could influence the number of PTI incidents. On the contrary, less incidents were recorded when the vertical gap size was 200 mm or less.

This observation is consistent with the findings of the NJDOT's study whereby the average maximum vertical gap size observed in the stations where the study was conducted was 333 mm. This placed them in the range where no correlation is observed between gap size and PTI incident frequency. It was concluded that by reducing large gaps, opportunities for gap injuries will also be removed and thus reduce the risk of PTI incidents.

According to the Railway Safety and Standard Board (2015) based in the UK, a horizontal gap size of 75 mm and a vertical gap size of  $\pm 50$  mm is considered safe for commuters and enables unassisted accessibility for PRMs. A study conducted in Melbourne, Australia (V. Moug, 2016) contradicts this standard and instead concluded that a horizontal gap size of 40 mm and a vertical gap size of 20 mm is the ideal gap size to ensure the safety of passengers and guarantee unassisted accessibility for PRMs.

The Metrorail line, however cannot adhere to these standards because it shares the railway line with freight and heavy haul trains. The Regulator Standard on railway stations (2015) requires a minimum clearance of 100 mm between the train and the platform to ensure safe travel through the station. Due to this limitation, PTI incident mitigation cannot be limited to platform design; human factors must be incorporated in the research to find the optimal solution to eliminating PTI incidents.

## **2.3. Methods of monitoring the gap size in train stations**

The gap between the train and the platform can be measured using the track geometry vehicle or manually on the track. A novel system of gap measurement was proposed in Japan using a 3D laser scanner and a stop-and-go operation where measurements of the gap clearance can be done on the platform (Shimizu, 2016). This method of measurement eliminates the need for track closure, thus making this system convenient and effective (expensive as it may be).

The use of open-source hardware such as Arduino technology can also be considered in the distance measurement between the platform and the train. Arduino technology is affordable and easily accessible. By combining distance measuring sensors with an Arduino microcontroller mounted on the platform, distance measurement between the train and platform can be obtained constantly. This option enables measurements to be performed during normal operational hours.

## 2.4. Train schedule reliability and its influence on passenger behaviour

On busy congested rail networks, random delays of trains are prevalent, and these delays have knock-on effects, which result in a significant or substantial proportion of scheduled services being delayed or rescheduled (Carey and Carville, 2000). The Metrorail network in South Africa is an example of a busy railway network that may require the redesigning of the current timetable. The current Metrorail timetable is plagued with delays and suboptimal train frequency allocation. The goal is to improve the current timetable in order to provide optimum commuting services.

Metrorail is infamous for having an unpredictable timetable and lengthy delays. This type of service delivery is as a result of factors such as: an inadequate timetable design, vandalism that results in less trains being available for operation, and operations being carried out in a degraded mode. According to Evans and Wener (2006), an unpredictable train schedule contributes to increased passenger psychological stress. This increased level of stress could result in aggravated behaviour of passengers in stations thus increasing the risk of incidents occurring.

Ideally, the Metrorail timetable should operate on an hourly basis according to operations (PRASA), however this is not the case. This schedule is not fixed and therefore difficult to predict. The unpredictability of this timetable leads to adaptation of degraded modes of operation which increases the risk of safety incidents occurring.

## 2.5. Cost of risk of occurrences

Currently, financial return is the most lucrative investment case in most infrastructure development in South Africa. Projects such as the PRASA Station modernisation program currently running is an example of a project where the primary focus was commercially driven. This in itself cannot be criticised, as it aims to encourage commuters to shift from road to rail usage thus generating higher revenue in the passenger rail and freight industry. However, if the issue of safety is not addressed at the same time, the ultimate objective of increased train ridership will not be achieved. Finding a way to define the cost of risk for passenger rail operations in South Africa would be the first step in motivating the need to address passenger safety issues adequately.

According to Van der Merwe et al. (2017), the systemic cost of risk for heavy haul operations can be expressed as the ratio between the cost of the railway occurrence (R/tonne) and the value of the commodity being transported (R/tonne), this ratio is then divided by the corridor density (Tonne-km per Route-km) to determine the cost of risk. Refer to Equation 1.

$$\text{Systemic Cost of Risk (\%)} = \frac{\text{Railway Occurrence Cost } \left(\frac{R}{\text{tonne}}\right)}{\text{Value of commodity transported } \left(\frac{R}{\text{tonne}}\right)} \div \text{Corridor Density (Tonne-km per Route-km)}$$

Equation 1

Using a similar approach, the cost of risk in terms of passenger occurrences and accidents can be determined. Once this cost has been clearly defined and quantified, safety related projects can be effectively motivated based on financial terms.

## 2.6. Discussion

During the 2015/2016 reporting period, the Railway Safety Regulator (RSR) reported 4250 operational occurrences. The number of fatalities and injuries during the same reporting period totalled 453 and 2290 respectively (RSR, 2015). These numbers indicate that the state of safety of South African railways requires further analysis to determine the real underlying cause of these statistics and the reason these numbers remain high despite investigations taking place. For this reason, research is required particularly in the South African context to determine the possible precursors of occurrences, incidents and accidents and identify means to eliminate and/or mitigate these precursors.

Investigating and quantifying the influence of human factors on safety in train stations, employing methods of constant condition monitoring in stations, optimising the train schedule, and developing methods of quantifying the cost implications of PTI incidents will contribute to the long-term objective of providing safe train transport for commuters. This will in turn encourage commuters to move from road to rail transportation.

## 3. TESTING AND RESULTS

### 3.1. Overview

A study was conducted in 2017 at Rissik Station, Pretoria, where the measurement of the gap size at the platform-train interface and an observation survey was carried out to determine the influence of the gap size on passenger behaviour. The findings of the study suggested that the gap size did not have an influence on passenger behaviour. However, the study identified other stress factors that could potentially contribute to PTI incidents. Factors such as a lack of communication, overcrowding and train design were identified as the three main stress factors that could result in PTI incidents at Rissik station.

### 3.2. Gap measurement between the train and platform

The gap measurement between the train and platform was carried out using open-source Arduino technology. Using the Arduino Uno R3 microcontroller equipped with two distance measurement sensors [an ultrasonic sensor (HC-SR04) and a laser sensor (VL53L0X)] as depicted in Figure 1, the static horizontal distance between the train and the platform was measured.

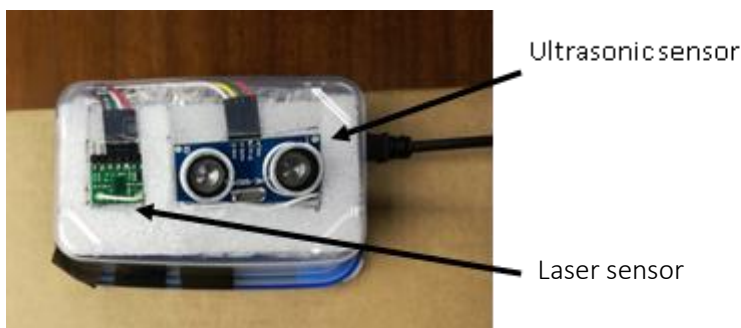


Figure 1: Distance measurement sensor prototype

Two prototypes were constructed and mounted at a 10 m interval on the edge of the platform as depicted in Figure 2.



Figure 2: Instrumentation set-up

Arduino technology was employed in this study because it was inexpensive and easily accessible. However, the distance measuring sensors proved to be unreliable in measuring distance in the presence of interference such as that caused by a moving train. Figure 3 illustrates the variability in the readings obtained.

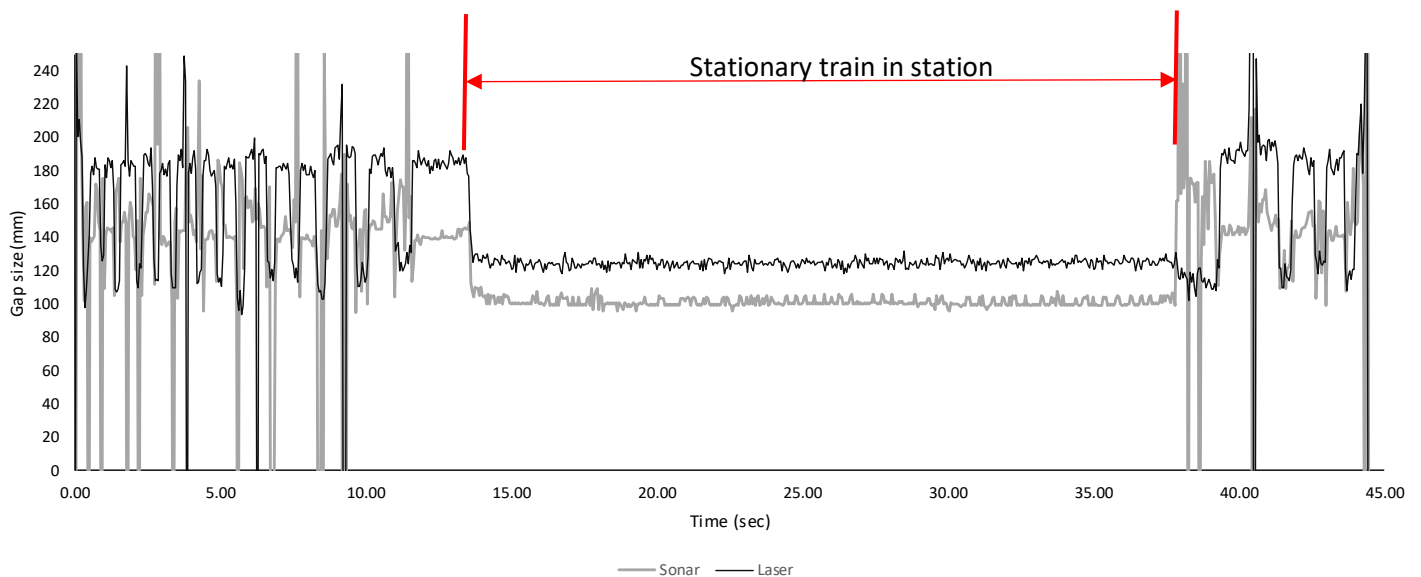


Figure 3: Readings obtained from distance measuring sensors

Both prototypes exhibited similar variability in distance measurement. The measurements were recorded at the recommended cycle period of 50 ms for a time interval of 45 seconds (which covered the dwell time of the train in the station) using both sensors. It was decided that an analysis of the data be conducted only on the readings obtained when the train was stationary. Properties of the data obtained are summarised in Table 1.

Table 1: Summary of data obtained when train was stationary in the station

	Sonar	Laser
Average distance between train and platform (mm)	324	345
Average distance between platform and train step (mm)	104	125
Standard deviation	38.21	2.49

The real horizontal distance between the platform and the train step was measured as 100 mm and the average vertical gap size was 50 mm. From the results obtained in Table 1, the ultrasonic sensor (HC-SR04) was the most accurate in measurement but had the least

reliable readings. The laser sensor (VL53L0X) was less accurate but had more reliable readings. It is recommended that further research be conducted in testing the feasibility of using these sensors for constant monitoring of the gap size in stations.

### **3.2.1. Findings on gap size**

The average horizontal gap size measured between the train and platform was 100 mm (considering the train step). According to the safety standards set out by the Railway Safety Regulator, this gap size is within the acceptable range to ensure the safe travel of passenger and freight trains through the station. This horizontal distance is however not to the standard set out by the RSSB (2015) to ensure unaided boarding and detraining of PRMs. The main limitation encountered in the gap measurement was the inability to obtain vertical gap size measurements using the Arduino prototype.

According to the study conducted by the RSR (2014), a gap size (vertical and/or horizontal) less than 200 mm will not influence the number of PTI incidents. With an average horizontal gap size of 100 mm and a vertical gap size 50 mm measured at Rissik station, it was expected that the gap at the PTI would not influence passenger behaviour. The study therefore sought to determine other possible stress factors that may result in PTI incidents.

### **3.3. Observation survey on passenger behaviour**

Using a data collection team of five observers and the aid of two digital cameras, data was collected at Rissik station over a period of one week in July 2017. A gap injury frequency analysis carried out by the NJDOT (2009) determined that 69 per cent of gap injuries involved women. For this reason, the observational study sought to distinguish between the behaviour of female and male passengers.

The data collected included:

1. The number and gender of passengers boarding and detraining;
2. The number of passengers looking down as they boarded or detrained;
3. The number of passengers carrying luggage or using a cell phone while boarding and detraining;
4. Identification of any other stress factors or behavioural characteristics of commuters that may increase the risk of a PTI incident occurring.

### 3.3.1. Results

**Error! Reference source not found.** presents the volume of commuters boarding the train at Rissik station. The days of the week that experienced the highest volume of commuters were Tuesday, Thursday and Friday. Friday experiencing the highest volume of the three days.

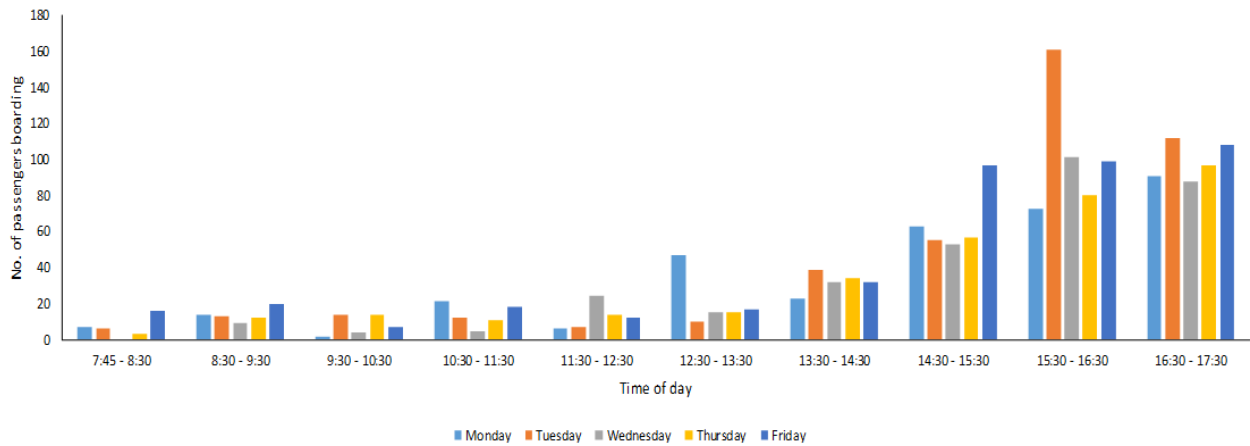
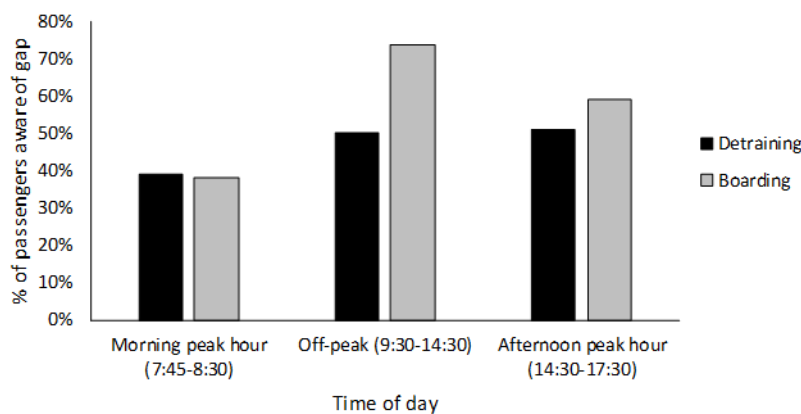


Figure 4: Total number of passengers boarding

### Figure 4: Total number of passengers boarding

Figure 4 indicates high volumes of passengers during the afternoon rush hour and this signifies overcrowding on the platform during these times. It was observed that overcrowding on the platform influenced passenger behaviour while boarding and detraining. During rush hour periods fewer passengers looked down while crossing over the PTI. This obliviousness to the gap presence is believed to increase the risk of PTI incidents. Consequently, overcrowding was identified as one of the major factors that contributes to PTI incidents. Figure 5 presents the percentage of total passengers aware of the gap (looking down) while crossing over the PTI.



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**Percentage of commuters aware of gap while boarding and detraining**

As previously highlighted, Figure 5 indicates that fewer passengers looked down while crossing over the PTI during the peak hour periods.



From the study conducted by the NJDOT (2009), it was observed that female passengers were less aware of the gap while crossing over the PTI as compared to male passengers. It was believed that this behavioural characteristic of female passengers resulted in 69 per cent of gap injuries having involved women. Figure 6 presents the difference in male and female commuter gap awareness when boarding and detraining at Rissik station.

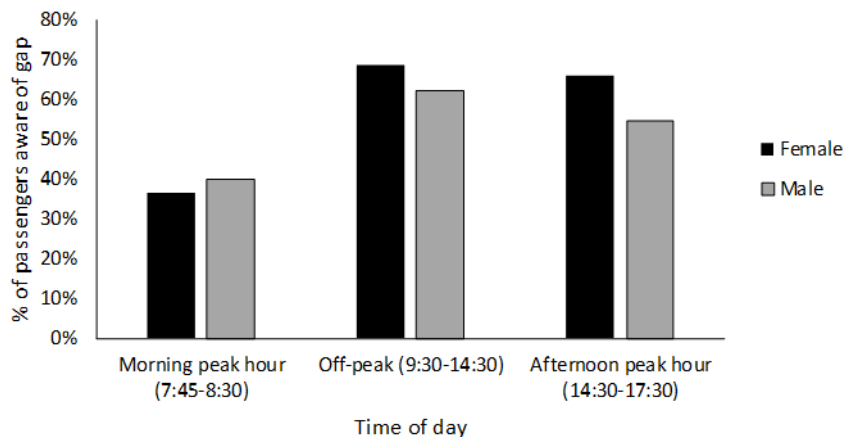


Figure 6: Percentage of passengers aware of the gap based on gender

Figure 6 indicates that female commuters were essentially more conscious of the gap compared to male commuters. The results presented in Figure 6 contradict the results obtained from the study carried out by the New Jersey Institute of Technology (2009). This observation could be used in designing safety campaigns to appeal to the relevant gender in the South African context.

### 3.4. Train schedule reliability

The study investigated the reliability of the train schedule at Rissik station. The train schedule was classified as reliable if majority (>50%) of the trains arrived at the station at the designated time. In the Metrorail context, a reliable train schedule would eliminate the issue of overcrowding in a single train. This overcrowding occurs because commuters have no information on the time the next train will arrive, thus creating a rush for the available train in the station.

The measure of the train schedule reliability at Rissik station is presented in **Error! Reference source not found.2**.

Table 2: Train reliability measure

	Tuesday	Wednesday	Thursday	Friday
%Trains on schedule	4%	6%	11%	30%
%Trains off schedule	96%	94%	89%	70%

*\*No delay allowance was considered*

From the results obtained in **Error! Reference source not found.2** it is clear that the Metrorail train schedule is critically unreliable. This unreliability coupled with a lack of communication resulted in severe overcrowding of passengers into the first train that arrived during rush hour. As previously highlighted, overcrowding increases the risk of PTI incidents,

therefore an unreliable train schedule and a lack of communication consequently increases the risk of PTI incidents.

Differences were identified between the Class 5M2A trains (yellow trains) and the new Class 10M4 (blue trains). It was identified that on average the yellow trains had a shorter dwell time than the blue trains. According to the study conducted by the RSR (2014), an extremely short dwell time results in passengers having to rush to board or detrain. Rushing, results in pushing and shoving during peak hours due to overcrowding and this increases the risk of PTI incidents occurring.

The yellow trains operated during the morning and afternoon peak hours due to their high passenger capacity. It was observed that the yellow train doors operate manually. It was also observed that most of the train doors remained permanently closed or open. This degraded mode of operation increases the risk of PTI incidents by either creating the opportunity for passengers to detrain and/or board while the train is moving (due to the open doors) or passengers having to rush to try and open doors that are stuck. The short dwell time of the yellow trains exacerbates the rush to board or detrain, thus increasing the risk of PTI incidents occurring.

It was observed that the average dwell time during the afternoon peak hour was longer than that during off-peak hours. This was expected due to the presence of more commuters boarding and detraining during this time. Dwell times dictate the arrival time of the train at the next station as well as the arrival time of other trains at the current station. An unnecessarily long dwell time causes delays throughout the train operation system, however, extremely short dwell times (such as with the yellow trains) place passengers at risk of falling during boarding or detraining due to insufficient time to cross over the PTI.

## **4. CONCLUSIONS AND RECOMMENDATIONS**

### **4.1. Conclusions**

The objective of the study carried out at Rissik station was achieved. The following stress factors were identified that may contribute to PTI incidents:

1. Lack of communication
2. Overcrowding on the platform and in the train
3. Train design
4. Unreliable train schedule

The stress factors identified correlate with some of the root causes identified by the RSR that are believed to result in PTI incidents occurring. Root causes such as “Communication” and “Rolling stock” (RSR State of Safety Report, 2017) just to name the two.

The study however, did not reveal a correlation between the gap size and PTI incidents as intended. This observation is consistent with the findings obtained from the study conducted by the RSR (2014), where no correlation was found between gap size and PTI incidents frequency when the gap size was smaller than 200 mm.

## 4.2. Recommendations

Improving information dissemination by upgrading the communication system at the station and increasing the staff on the platform for crowd control (during rush hour especially) would significantly reduce the risk of PTI incidents. Providing universal accessibility for PRMs as well as stroller users would increase train ridership and improve safety in the station and at the platform. Future research should include the vertical gap size measurement, for it is believed that the vertical gap has a more significant influence on safety and accessibility at the PTI (Moug et al., 2016).

The next phase of the study should be to observe passenger behaviour at a station where the average horizontal and vertical gap size are larger than 300 mm in order to make a comparison on passenger behaviour observed in the two scenarios. The findings of the comparison will provide a quantifiable deduction on the effect of the PRASA Station Modernisation project currently running.

Research should explore ways of quantifying the indirect costs incurred by society due to train incidents in order to accurately determine the true cost of risk of passenger related incidents. Further research should also be conducted on the feasibility of employing Arduino technology for constant gap size monitoring at train stations.

Statistical techniques should be employed in determining the relationships that exist between the stress factors identified in the study. Development of statistical models that describe these relationships would give engineers and train operators the ability to quantify and consequently control these stress factors, thereby mitigating the risk of PTI incidents occurring.

## 5. ACKNOWLEDGEMENTS

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