POTGIETER STREET: ROAD SAFETY PROJECT

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ABSTRACT

Potgieter Street, one of the major access routes to the Central Business District (CBD) of the City of Tshwane, has become notorious for runaway heavy vehicle accidents. Although measures were implemented previously to improve the situation, it became apparent that these measures did not yield the anticipated effect of drastically reducing accidents. This paper gives an overview of comprehensive investigations that were undertaken to understand the causes of accidents and to investigate additional measures to reduce the risk of heavy vehicle accidents.

1. INTRODUCTION

Potgieter Street, one of the major access routes to the Central Business District (CBD) of the City of Tshwane, has become notorious for runaway heavy vehicle accidents. It is the extension of the N14- and R101- routes (provincial) which merge before Potgieter Street, which in turn leads to the CBD environment. The accidents are often serious in nature and are newsworthy events that attract public and political attention.

Although measures were implemented to improve the situation, it became apparent that they did not yield the anticipated effect of reducing accidents. This paper gives an overview of comprehensive investigations that were done to understand the causes of accidents, as well as the investigation of additional measures to reduce the frequency of heavy vehicle accidents, and more specifically, the catastrophic consequences of a heavy vehicle speeding out of control down Potgieter Street.

2. STATUS QUO

2.1 The Road Environment

The study area included an eight kilometre section of the N14, starting just before the pipe bridge at Snake Valley across the N14 down to the Bloed Street / Potgieter Street intersection. A section of the R101, approximately 4 km south of the Pretoria Central Prison, was also included in the study. The road alignments are shown in Figure 1.

The vertical alignment of the N14 consists of a total fall of approximately 180 m over a distance of 5,7 km. From the pipe bridge down to the Eeufees Road bridge is a steep downgrade of 5,1%, followed by an uphill over a short distance, followed again by a relatively steep downgrade again of 3,5% to 4% from the truck stop to the end of Potgieter Street. A long section of Potgieter Street is also shown in Figure 1.

The R101 has a constant fall (2% to 3%) from the top of the hill at Thaba Tshwane and descending gradually towards the merge with the N14.

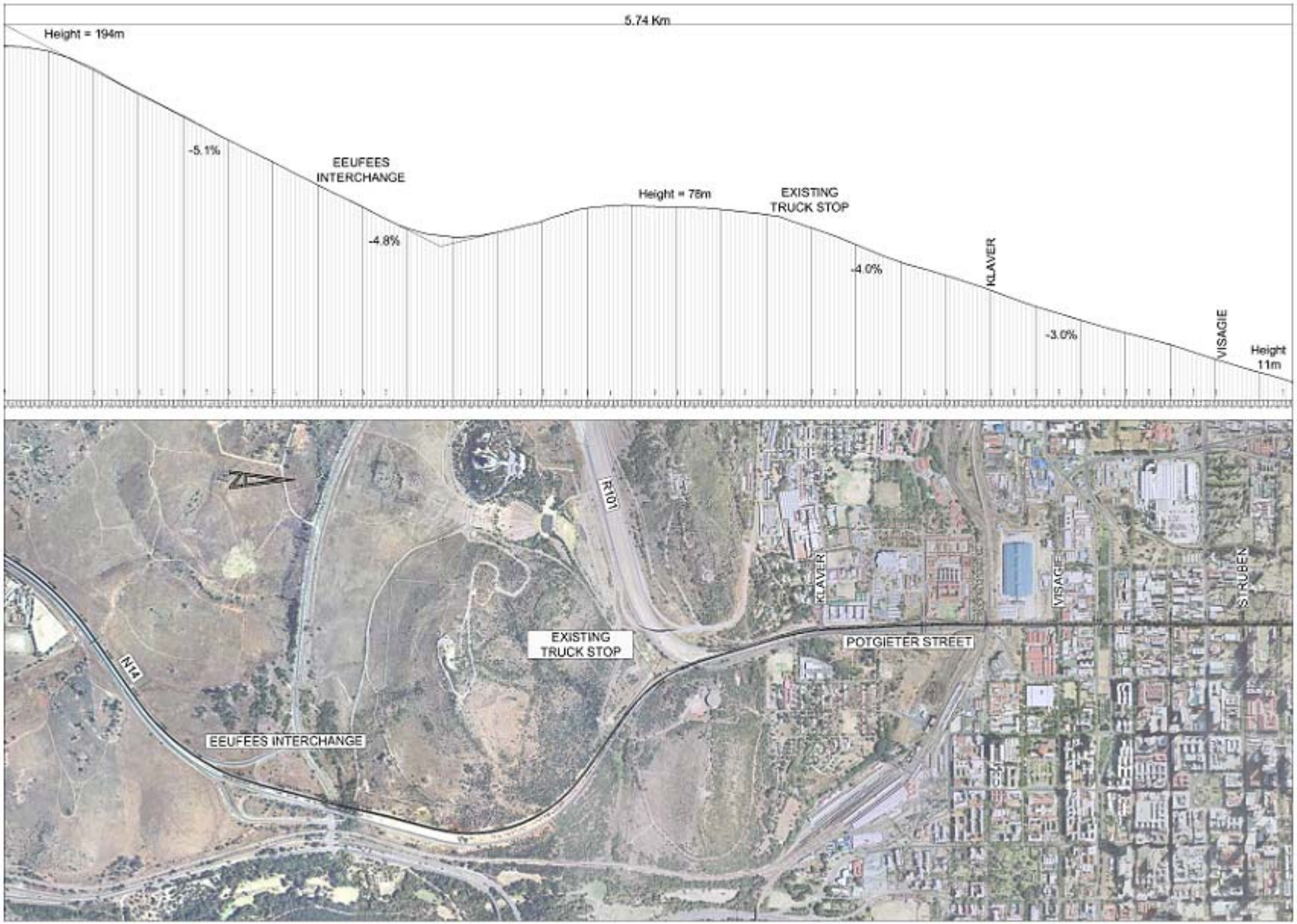

Figure 1. Layout of study area and long section of the N14 and Potgieter Street.

2.2 Traffic Volumes

The traffic volumes (south to north) on Potgieter Street for a 12-hour period (06:00– 8:00) on a typical weekday are shown in Table 1:

Table 1. 12 hour traffic counts.

	12 hour, 06:00 – 18:00 (south to north)			a.m. peak hour
	All vehicles	Heavy vehicles	% Heavy Vehicles	Heavy vehicles
From N14	20 000	1 500	7,5	100
From R101	8 900	360	4,0	23
Total	28 900	1 860	6,4	123

The above figures show that ±80% of the heavy vehicles enter Potgieter Street from the N14.

A 12-hour count of buses and heavy vehicles was undertaken on the N14 as well as the R101 during May 2004. The vehicles were stopped along the roads and their Gross Vehicle Masses (GVM) were recorded. The vehicles were also classified according to number of axles. The counts were only taken of vehicles entering Potgieter Street (travelling northwards).

Nearly half of the trucks travelling on the R101 are 2-axle single-unit trucks with single wheels on the rear axle (4 wheels total). Most of the remaining trucks are 2-axle single-unit trucks with double wheels on the rear axle (6 wheels total). A small percentage of trucks are articulated.

On the N14, only 1 in 5 trucks are 2-axle single-unit vehicles with 4 wheels total. Nearly half of the trucks are 2-axle single-unit vehicles with 6 wheels. Articulated vehicles constitute 1 in 4 of the trucks.

2.3 Accident Statistics

Accident statistics of the most serious heavy vehicle accidents over the past four and a half years indicated the following:

- There were 15 accidents that caused fatalities or serious injuries. SAPS case dockets were opened for all of them.
- In these accidents 21 people were killed while 63 people were injured. In a single accident on 5 October 2003, 14 people were killed and 4 injured. This illustrates the severe risk of a runaway truck causing serious accidents with multiple fatalities.

Seven of the 15 SAPS case dockets were analysed by accident reconstruction experts to provide insight into the causes of the accidents.

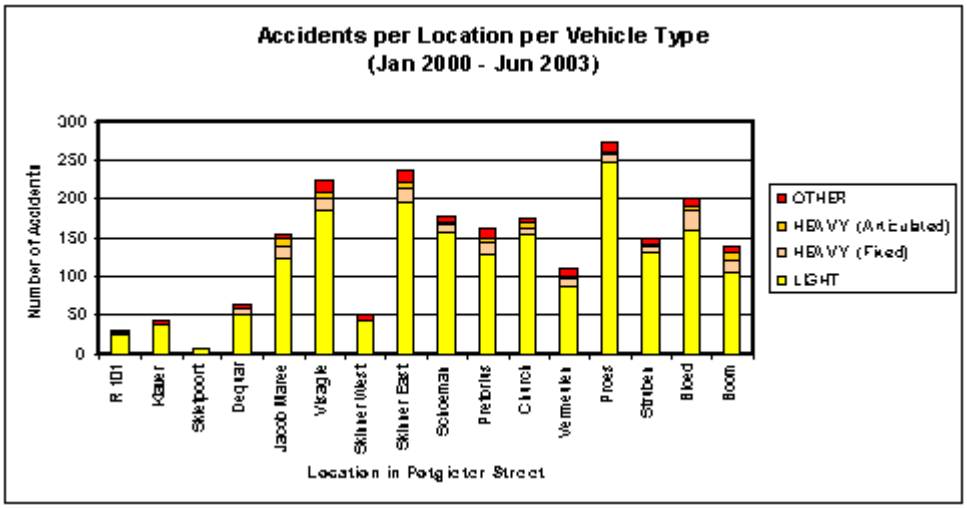

Figure 2. Accidents per location per vehicle type (Jan 2000 - Jun 2003).

The types of vehicles involved in accidents along Potgieter Street are shown in Figure 2.

2.4 Accident Reconstructions

Accident reconstruction of seven "runaway truck" accidents was carried out. Five of the accidents occurred between the morning peak hour and midday, while the other two occurred in the early and late afternoon respectively. In all the instances the runaway vehicle was an articulated truck.

The following scenario was similar in most of the cases. The driver entered Potgieter Street while engaged in high range gear. When the driver had to slow down and applied brakes, the vehicle did not slow down as anticipated and the driver attempted to engage a lower gear. Owing to the speed of the vehicle the lower gear did not engage and the driver lost control of the vehicle.

The primary causes for these accidents, from a mechanical point of view, are summarised as follows:

- Total brake system malfunction
- Worn brakes
- Incorrect brake adjustment
- Brakes of vehicle overheating
- Glazed brake shoes
- Trailer brakes not functioning
- Failure of mechanical components

An important conclusion from the accident reconstructions was that in some cases a combination of factors, and not only one of the above, contributed to the accident.

2.5 Speed Surveys

Speed surveys were done at various locations to determine the speed with which heavy vehicles are descending on the downgrades.

The most important finding from the speed surveys is that the 85% percentile speed of heavy vehicles at the Eeufees Road Bridge (bottom of the first downgrade of 5,1%) is 99 km/h. Considering the legal speed restriction of 80 km/h, this is high and confirms that most heavy vehicles do not engage low gear as advised by the road signs on top of the first downgrade.

3. DESCRIPTION AND EVALUATION OF PREVIOUS MEASURES

3.1 Measures Stemming from the 1998 Study

The former City Council of Pretoria conducted a traffic safety investigation for Potgieter Street in 1998, from which specific implementation proposals were made.

Some of the proposals were implemented, including the following:

- A compulsory truck stop to the south of Potgieter Street on the N14.
- Erection of road traffic signs and markings.
- Street lighting along Potgieter Street up to the truck stop.
- Red light violation and speed enforcement camera at the first signalised intersection as vehicles enter Potgieter Street.

Further measures that were proposed (but not implemented) included the construction of an additional lane on the N14, upstream of the truck stop, as well as an arrester bed at the truck stop. It was decided to delay the implementation of these measures until the effectiveness of the implemented measures could be evaluated.

It is difficult to evaluate and/or quantify the effectiveness of measures such as road signs and -markings, although the high speeds at the bottom of the first downgrade indicate that drivers are not

adhering to the speed limit and thus are ignoring the road signs to engage low gear. Furthermore, the existing truck stop was ignored in the absence of visible law enforcement. It is not possible to enforce the utilisation of the truck stop with traffic officers on a 24/7 basis because of manpower shortages and substantial costs linked to such an operation.

Initially the incidence of heavy vehicle accidents decreased but averaged at over three per year for the past four and a half years.

3.2 Law Enforcement Action in 2003

Following a serious accident on Sunday, 5 October 2003, a temporary truck inspection area was commissioned on the N14 at the Snake Valley Road interchange, approximately 1,5 km south of Potgieter Street. This inspection area was manned on a 24-hour basis for a period of six weeks.

Roadworthy investigations were carried out on 6450 trucks of which 2048 trucks (or 31,8%) were found to have some defects warranting prosecution. Offences included lights not working, oil leaks, deficient brakes, unserviceable tyres, overloading, and invalid registrations and/or licences. Forty-four (44) heavy vehicles (0,7%) were found to have serious defects warranting suspension of further travel. This resulted in on-site repairs to the defective trucks with some requiring heavy vehicle recovery. Most of these 44 trucks posed a serious risk to other road users which could have had serious consequences in the high traffic density environment of Potgieter Street.

4. UNDERSTANDING THE PROBLEM

4.1 Maintenance of Vehicles

The results from the law enforcement campaign indicate that the level of maintenance on heavy vehicles is inadequate and this is a significant contributory factor to the causes of accidents. It was also found that a substantial number of heavy vehicles diverted to other routes once information became known of the increased law enforcement actions.

4.2 The Driver

Factors related to the driver's causing or contributing to accidents include the following:

- The main problem associated with driver incompetency stems from inadequate training and discipline. Drivers with poor training do not understand the impact of their actions such as driving unroadworthy vehicles and not adhering to speed limits. Drivers without discipline may have received proper training, but do not put training into practice (exceeding speed limits, not adhering to low gear signs, not conducting regular safety inspections etc.).
- Drivers do not have specific training on how to handle downgrades and emergencies with brake failure. Failing brakes is an ever-present risk and a driver that has not been properly trained and drilled how to handle such a situation, may panic and then not be able to utilise facilities such as arrestor beds.
- Law enforcement actions are aimed at ensuring that the driver drives a roadworthy vehicle that is not overloaded, adheres to the required speed limit and stops at the truck stop. Owing to limited law enforcement actions, drivers lack discipline and do not obey regulations.
- The fact that drivers are liable if a vehicle is overloaded and not the owner of the vehicle is seen as a problem that also needs to be addressed through legislation. Drivers are in many cases not in a position to decline to drive an overloaded vehicle without the risk of losing their employment.

4.3 The Vehicle

4.3.1 Lessons Learned from Accident Reconstruction

The study on the reconstruction of accidents confirmed that brake failure is the primary cause of accidents. Brake failures, however, occur due to a number of contributory factors as described in

this paper.

4.3.2 The Braking System

Brake failure was identified as one of the main causes of heavy vehicle accidents on Potgieter Street. There are various reasons why brakes fail, such as poorly maintained or even non-functional brakes, but probably one of the most important reasons is the injudicious application of brakes in situations where low gears should have been used.

To explain the problem with the brake systems on heavy vehicles, it is necessary to consider the general functioning of heavy vehicle brakes. In most situations, an air system (not fluid as in cars) is used to engage brake shoes. There are mainly two types of air systems in use, namely the Direct Pressure and Spring Systems. In the Direct Pressure System, the brakes are engaged by direct pressure while in the Spring System, the brakes are engaged by springs and the air is used to release the brakes. Most heavy vehicles are supplied with the Spring Brake System due to the inherent safety advantages.

In the Spring Brake System, brakes are initially in the locked position when a vehicle is started. Air is then pumped into the system which "releases" the brakes. When the driver applies the brakes, the air is released and the springs engage the brakes. The result of this system is that, when air is vented from the system (with, e.g., a pipe burst), the brakes will operate as parking or emergency brakes. In theory, a vehicle should be able to stop in the event of failure of the air system or compressor since the brakes should be automatically engaged and bring the vehicle to a stop.

The problem with the Spring Brake System is that when brakes are applied continuously or in short succession, such as when a driver incorrectly applies the brakes when driving on a downhill, the available air pressure drops because the pressure pump is not able to restore pressure quickly enough. A pressure tank is provided on all heavy vehicles, but this tank has a limited capacity and cannot provide for continuous use of brakes. The pressure drop results in the release of the springs and the resultant constant application of the brakes. This causes overheating of the brake drums, which can lead to the glazing of brake shoes or even in brake failure. The glazing of the brake shoes results in a low friction which is often experienced by drivers as a "fading" of the brakes.

To avoid the above problem, the only solution is for the driver not to brake continuously or in short succession. When driving on a downhill, the driver should engage low gear or a retarder if fitted and apply the brakes of the vehicle as sparingly as possible. The problem with engaging the low gear is that it results in very slow speeds (less than 40 km/h), something that many drivers wish to avoid for the simple reason that driving at 40 km/h will result in a travel time of 6 minutes from the top of the hill to Klawer Street compared to 2,5 minutes at 100 km/h.

4.3.3 Potential Energy and Speed

To understand the impact of the potential energy of the steep hills on the speed of a truck without brakes, several speed profiles were developed. This was done using the Veki39 software programme, developed by Dr Martin Slavik.

All analyses were done assuming *a truck is not engaged in any gear and has no brakes, also referred to as the coasting mode*.

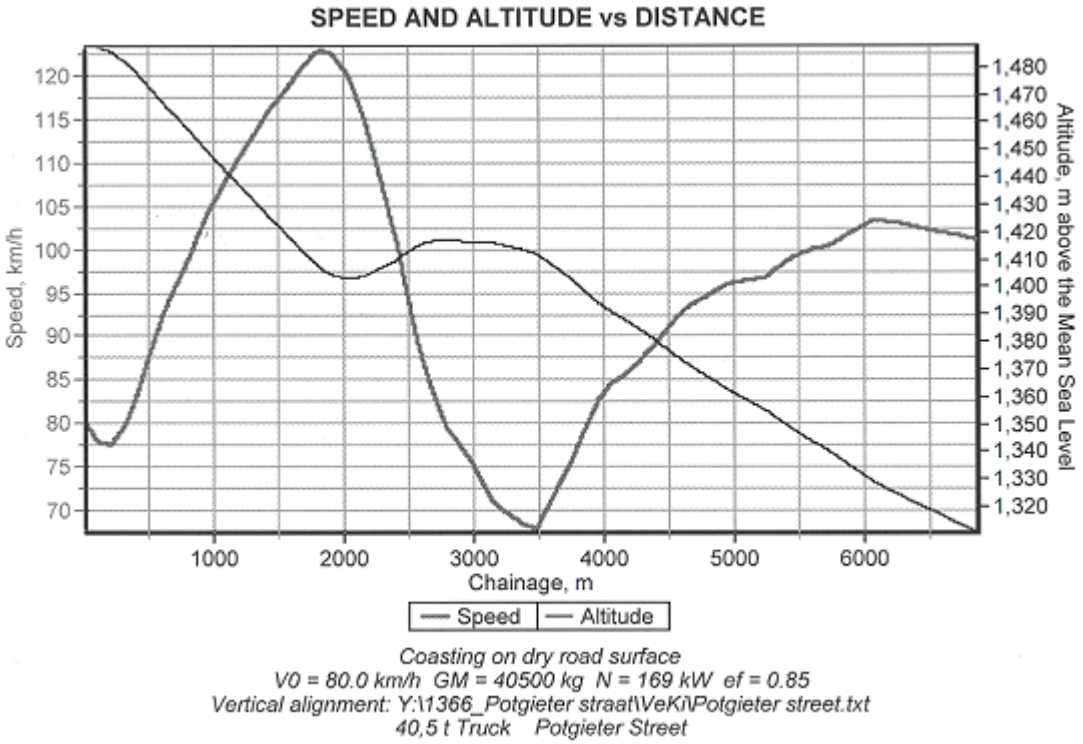

Figure 3. Speed profile: N14.

From the speed profiles, the following deductions were made:

- A heavy vehicle arriving at 80 km/h at the Pipe Bridge on the N14, would reach a speed of 124 km/h at the bottom of the first downgrade and would go over the second hill and reach a speed of 103 km/h at Bloed Street. The speed profile of this scenario is shown in Figure 3.
- Even at a very low speed of 10 km/h at the Pipe Bridge, the heavy vehicle would still go over the first hill, reaching 56 km/h at the truck stop and 80 km/h at the first traffic signal. The deduction that can be made from this is that even if a vehicle drives slowly on the first downgrade, but does not have low gear engaged and the brakes fail somewhere along the downgrade, it will still go over the first hill and enter Potgieter Street at a dangerously high speed.
- A truck that has stopped at the truck stop, and whose brakes fail immediately thereafter, will reach a speed of 95 km/h at the bottom of Potgieter Street. The rate of acceleration on the second downgrade of 3,5%, is however, significantly less than on the first downgrade of 5,1%, as can be seen by the slope of the speed profile in Figure 3.

A heavy vehicle arriving at 80 km/h at the top of the hill on the R101, would reach a maximum speed of 114 km/h at Bloed Street.

4.3.4 The Environment

The long downgrades of 3,5% and 5,1%, combined with the fact that these downgrades terminate in a city environment with several crossing streets, is the reason why runaway trucks present such a large safety problem.

The driver entering the city can also have the perception that he is driving in freeway conditions, for the following reasons:

- The N14 cross-section consists of two 10,5m wide carriageways. Each carriageway is divided into two 3,7m wide lanes with shoulders on either side of the lanes.
- There is a 9m wide median island dividing the carriageways.

- Up to a point just before the truck stop, the driver has no view of the city street he will be entering. Therefore, if a driver is not familiar with the road, he is dependent on the road signs to convey this message to him.
- Although there are road traffic signs indicating that heavy vehicles should engage lower gear as well as signs indicating the compulsory truck stop, it is clear that the message is not conveyed clearly enough, or it is not perceived to be credible.

The existing truck stop on the N14 was placed 600m upstream of the merge between the N14 and the R101. This was the most practical point to place the truck stop in terms of available space. It is also the position where the speed of a coasting vehicle is the lowest. The existing entry lane to the truck stop was found to be too short and must be extended to improve operation of the truck stop.

The problems created by the road environment (major arterial going into CBD environment) are inadequately communicated to the driver and the critical conditions are not accommodated.

4.4 Problem Definition

Several factors cause runaway trucks in Potgieter Street with different probable outcomes. However, on account of the publicised nature of these accidents, it was necessary to develop a problem statement that can be reasonably understood by the general public. This reads as follows:

The N14 and R101-Freeways have steep downgrades leading into Potgieter Street and the CBD of the City of Tshwane. Potgieter Street also has a relatively steep downgrade over a distance of 3 km. Heavy vehicle accidents occur due to brake failures on these vehicles and other causes such as driver error. Brake failures are caused by a number of contributory factors such as inadequate maintenance of vehicles, driver incompetency due to inadequate training, lack of driver discipline (exceeding speed limits, not adhering to low gear signs, overloading of vehicles etc). The change in road environment from freeway to urban road conditions is not communicated effectively and inadequate law enforcement leads to speeding and disregard of road signs.

During the investigation it became evident that the N14 leading into Potgieter Street posed the biggest problem, as 80% of heavy vehicles originated from the N14. The balance entered from the R101. The R101 however also poses a risk in terms of heavy vehicle runaway trucks due to its downgrade of 3,5%, as drivers expect it to be less.

5. DEVELOPMENT OF SOLUTIONS

5.1 Approach

An alternative solution could be that all heavy vehicles entering Potgieter Street should be rerouted to one of the routes, e.g. the R101 and that measures should only be implemented along that route. The study to determine the feasibility of using only one route has not been completed, but preliminary investigations indicate that this would not be cost effective. Subsequently, measures were investigated along both routes.

Based on the problem statement above, a range of solutions were investigated. These measures can be divided into preventive and mitigating measures. Preventative measures are aimed at reducing the risk of a runaway truck whereas mitigating measures are aimed at limiting the impact of a runaway truck. It is also accepted in the development of solutions that given the road environment, possible mechanical failure of trucks and the human factor of drivers, it will be impossible to reduce the risk of a runaway truck to zero.

The approach was further to determine which solutions, be it preventive or mitigating would have the highest benefit at the lowest cost. It was also necessary to make provision for a phased implementation as funds become available. The use of technology (Intelligent Transport Systems),

such as classified electronic camera law enforcement, was also investigated as an alternative.

5.2 Preventive Measures

5.2.1 Warning and Awareness

Increased warning and awareness of the problem need to be developed on several levels, namely:

- Driver training and discipline need to be addressed on a national level through improved training. The South African Road Freight Association must be informed of the findings of the study regarding the large number of trucks that were found with serious defects and the lack of accountability taken by many owners of heavy vehicles. Training of drivers and implementation of pre-trip inspections are essential to improve the safety record of the industry.
- Additional warning and awareness of the changing environment on the N14 through additional road traffic signs and markings need to be implemented. Road markings such as COSBI strips are seen as more effective than road signs alone and should be implemented.
- Law enforcement must be stepped up through the implementation of electronic enforcement options such as cameras which can operate on a 24/7 basis.

5.2.2 Enforcing Lower Speeds

The most effective measure to prevent brake failure or overheating of brakes would be to force heavy vehicles to engage low gear, as described in Section 4.3.2. Low gear is defined as a gear in the lower range where it will not be necessary to use brakes to slow down a vehicle or maintain appropriate speed. Based on the information of trucks supplied by the mechanical engineer on the team, the most effective way to achieve this is to reduce the speed limit to below 40 km/h. This must be enforced at several locations, otherwise trucks only slow down locally at the speed camera.

Reducing the speed of heavy vehicles to 40 km/h, implies that an additional lane will be required to provide adequate capacity on the N14. As this has cost implications it will not be possible to implement this recommendation immediately.

In the interim the speed of heavy vehicles could be reduced to 60 km/h and the speed of other traffic to 100 km/h. This would be from the Eeufees Road off-ramp to the truck stop. Although this would not support the ideal of enforcing a lower range gear selection, it would reduce speeding and should have a positive impact on the risk of runaway trucks.

Classified camera law enforcement is essential to make this measure effective.

5.2.3 Existing Truck Stop

The existing truck stop is the last facility where a driver can confirm that the brakes of his vehicle are in working order, before he enters Potgieter Street and the CBD. It is essential that heavy vehicles utilise this facility and enforcement to ensure this must be done through classified camera law enforcement or a height restriction barrier.

A set of traffic signals per lane must also be installed at the truck stop to ensure that heavy vehicles stop at the stop line. Cameras should be installed to enforce the stopping.

5.3 Mitigating Measures

Despite the provision of preventive measures, the risk of a runaway truck will always remain due to human error or mechanical failure. Therefore, mitigating measures to reduce the impact of a runaway truck were investigated.

A critical element in selecting appropriate mitigating measures is that it must be assumed that the largest portion of drivers that have lost control of their vehicles will panic and react illogically. The driver must, therefore be provided with as much time as possible to react and the measures implemented, must be as accessible as possible. It must also not be provided too early along the

road, as the driver may still have the perception that he will bring the truck to a standstill. Road signs and markings must assist the driver in decision making.

In the case of Potgieter Street, the further down the road mitigating measures such as an arrester bed is installed, the higher the risk of accidents at cross intersections.

Measures investigated included five locations for an arrester bed and the alternative of providing a dragnet. The dragnet consists of a series of cable nets across an escape lane. Owing to the large replacement cost and the fact that no other example exists in South Africa, it was decided not to use this alternative.

Five possible locations were investigated namely:
- At the existing truck stop;
- After the merge of the N14 and the R101 through the Klawer Street intersection in front of the Central Prison;
- Between the railway bridge and Visagie Street;
- At the end of Potgieter Street near the Belle Ombre Station; and
- On the R101 at the off-ramp to the SA Defence Force area.

Initially the alternative to provide an arrestor lane and arrestor bed at the Klawer Street intersection was also indicated as probably the most feasible option. During further investigations, however, it became apparent that this location would create problems for heavy vehicles that have to weave across the incoming lanes from the R101 as well with vehicles standing at the Klawer Street intersection. Although a dedicated lane was envisaged at this intersection, the risk of vehicles stopping in that lane is considered to be a problem.

The positioning of arrestor beds is complicated by the fact that there are two approach routes, the N14 and the R101, which merge at a point where traffic are already slowed down at the first traffic signal. The arrestor beds, therefore, have to be placed before this point where the density of traffic increases significantly and the risk of a runaway truck colliding with traffic is high.

There are three critical elements that must be considered when providing an arrestor bed, namely:
- Dedicated truck lanes ahead and also after the truck stop/arrestor bed to enable the enforcement of lower speed for heavy vehicles;
- Heavy vehicle stop to confirm whether the brakes are in a working condition and to reduce speed; and
- An arrestor bed for vehicles which experience brake failure. The arrestor bed requires the installation of a gravel bed together with a short arrestor lane ahead of the arrestor bed.

The most suitable positions for arrestor beds were identified at the existing truck stop and on the R101, before the off-ramp to the SA Defence Force area.

5.4 Proposed Solutions and Estimated Cost

The proposed solutions and estimated cost are shown in Table 2.

5.5 Expected Effectiveness of Measures

An attempt was made to indicate the effectiveness of the measures from a statistical point of view. This was used to prioritise the measures.

Table 2. Proposed measures and estimated cost.

Proposed measures	Type of measure	Estimated cost
Preventative measures		
1.Road signs and markings	Road signs	R 186 000,00
2.Camera law enforcement	Cameras	R 1 210 000,00
3.Road markings (COSBI lines and other lane markings)	Lane markings	R 45 000,00
Total		**R1 441 000,00**
Mitigating measures (N14)		
1. Arrestor bed at existing truck stop, including arrestor lane	Arrestor bed	R 2 000 000,00
2. Widening existing bridge over service road	Bridge	R 715 000,00
3. Road signs and marking to indicate arrestor bed + gantries to indicate signage	Road signs	R400 000,00
4. Truck lane from truck stop to top of hill	Add lane	R 9 942 000,00
5. Truck Stop traffic signals and camera enforcement	Signals and camera	R 700 000,00
Total		**R 13 757 000,00**
Mitigating measures (R101)		
1. New truck stop and arrestor bed		R3 382 000,00
2. Camera enforcement of truck stop	Camera	R 400 000,00
3. Gantries to indicate road signs and arrestor bed		R400 000,00
4. Street lighting		R350 000,00
Total		**R4 532 000,00**
TOTAL COST		**R 19 730 000,00**

It was found that:

- Measures to reduce speed including measures such as forcing heavy vehicles into a lower gear range and providing cameras and an additional lane to reduce the speed limit could reduce accidents by 40%; and
- A 76% reduction in heavy vehicle accidents can be expected should all the recommended measures be implemented, including the arrester bed.

These numbers were, however, arrived at by making several assumptions regarding driver behaviour, mechanical failure and prevailing roadway conditions. These numbers should, therefore, only be seen as a means to assist in decision making.

6. CONCLUSIONS

The Potgieter Street Road Safety Project provides good insight into the causes of heavy vehicle accidents as well as measures that can be implemented to reduce the risk of run-away truck accidents.

There are many factors contributing to the cause of these accidents, which can be classified according to the behaviour of the driver, the condition of the vehicle and the road environment.

Heavy vehicle accidents can be reduced if these vehicles can be forced to reduce speed timeously and to engage low gear. This is regarded as the most critical element of the solutions proposed for Potgieter Street. Other solutions, such as additional road signs and mitigating measures such as an arrester bed, are also expected to result in a reduction of accidents.

Although the proposed measures will not eliminate the risk of accidents completely, it is expected to reduce the risk of runaway trucks significantly.

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BIOGRAPHY

Hilton Vorster is responsible for traffic engineering in the Roads and Stormwater Division of the City of Tshwane Metropolitan Municipality. He holds an Honour's Degree in Transportation Engineering from the University of Pretoria. He has also completed an Executive Leadership Programme from the University of Pretoria. He has served on a number of National Committees for the development and revision of Guideline documents and manuals. He has presented a number of papers on traffic calming, Intelligent Transport Systems and road safety, at national and international conferences.