GIS BASED IDENTIFICATION OF HAZARDOUS LOCATIONS IN THE WESTERN CAPE

M VANDERSCHUREN*, A JANMOHAMMED*, S PHAYANE* and M ARENDSE**

*University of Cape Town, Centre for Transport Studies, South Africa
**Western Cape Government, Transport and Public Works, South Africa
email: marianne.vanderschuren@uct.ac.za

ABSTRACT

South Africa is known for its high level of road fatalities (Vanderschuren et al., 2017). In order to curb the problem, various solutions have been proposed, with mitigation efforts achieving varying level of successes between provinces. In the Western Cape, despite substantial improvement to combat the road safety burden, more needs to be done to continue this downward trend.

As part of the recent “Western Cape Road Safety Implementation Plan” development, fatality data for the years 2011 to 2015 was taken to a local level. Absolute fatalities, as well as the fatalities per 100 000 population, were compared. Location specific data was also available, providing an opportunity to use a Geographic Information System (GIS) to assist in the analysis.

This paper starts with a comparison of road safety trends in various South African provinces, followed by a location specific analysis that identified the top ten hazardous locations for the six districts in the Western Cape *viz* Cape Town Metropole, West Coast, Cape Winelands, Overberg, Central Karoo and Eden districts. Based on a desk top review of the local circumstances and an identification of feasible road safety measures, the research team provides the necessary guidance for further implementation to the local authorities.

1 INTRODUCTION

In March 2013, the World Health Organisation (WHO, 2013) revealed concerning trends in the Global Status Report on Road Safety 2013: Supporting a Decade of Action. The report presents 2010 data for 182 participating countries and provides a baseline for monitoring the ‘Decade of Action for Road Safety’ (2011 - 2020). The report shows that about 1.24 million road traffic deaths occurred throughout the world in 2010, indicating a stabilisation since the publication of the first status report in 2009. Middle-income countries have the highest annual road traffic fatality rate at 20.1 per 100 000 population, compared to 8.7 and 18.3 per 100 000 population in high- and low-income countries, respectively (Peden et al., 2013).

In South Africa, provinces have had varying levels of success in combatting the road safety burden. This paper elaborates on the provincial differences and describes the way forward, chosen by the Western Cape Government, after the downwards road fatality plateaued at -28% since 2009 (Vanderschuren et al., 2017).

2 METHODOLOGY

There is a significant difference in the number of fatatilites when comparing high-income countries to low- and middle-income countries, with the former having almost 2.5 times less fatalities than the latter (Wegman, 2017). This suggests that there are external factors that affect road fatalities. Initially, a literature review identified external factors, such as population, GDP and motorisation. Based on this, an analysis of these external factors for South Africa and, where possible, the various provinces, was carried out. Multiple National data sources were used to perform the analysis – the Road Traffic Management Corporation (RTMC) annual reports, data from Statistics South Africa (Statistics SA) and the electronic National Traffic Information System (NaTIS, the real-time database that records the vehicle fleet), amongst others (see Figure 1).

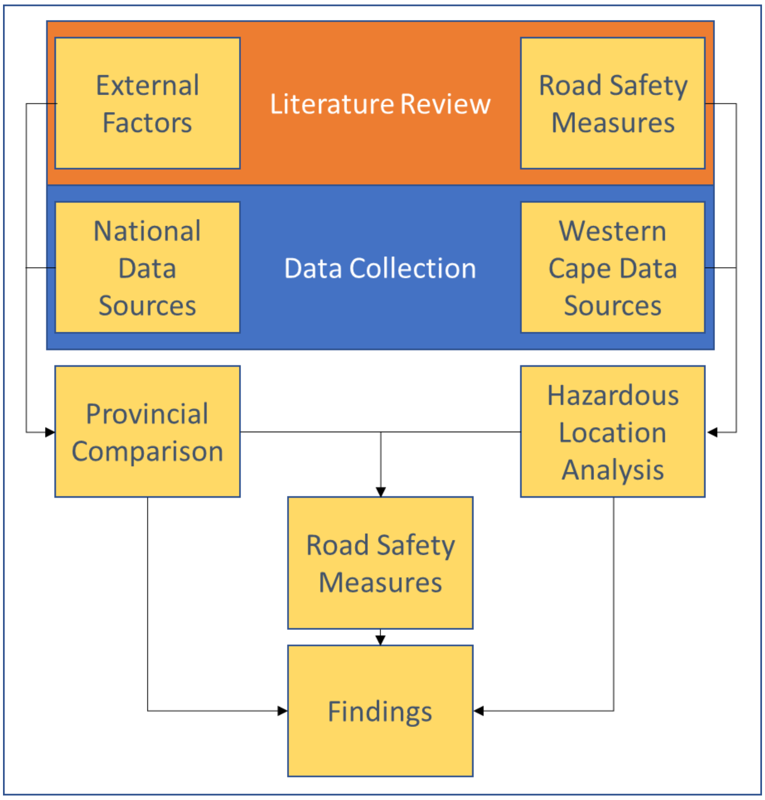


Figure 1: Methodology Flowchart

3 IMPACT OF POPULATION, GDP and MOTORISATION ON ROAD FATALITIES

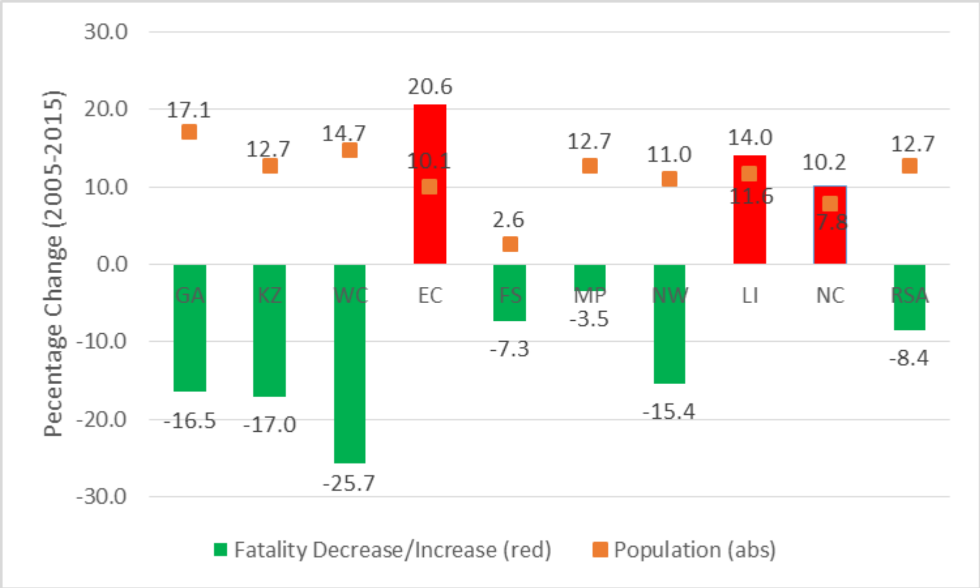
Data from RTMC provided annual fatalities and annual vehicles registered in each province during the 2005-2015 period, while reports from STATSSA helped to identify the population in each province and their contribution to the national GDP. Using the extracted data, an analysis was performed to compare the performance of various provinces, over the years, and identify the impact of the external road safety variables on the annual fatalities and the annual fatalities per 100 000 population.

Detailed information, i.e. provincial information from the intelligent Provincial Accident System (iPAS) and the provincial Forensic Pathology System (FPS), for one of the provinces, namely the Western Cape, was used to identify hazardous locations. Moreover, local GIS based road information and 'Google Street View' assisted in identifying the top ten hazardous locations and potential measures to combat road fatalities and injuries.

Road crash risk developments, over time, are typically correlated with mobility developments, as expressed in the number of vehicle-kilometres of travel. These mobility estimates are, in turn, affected by socio-economic factors reflecting the level of motorisation in a country, the economic growth and the level of prosperity overall (Yannis et al., 2014). In this section, literature-based findings for population levels, GDP levels and vehicle ownership, and how they relate to road safety, are elaborated upon.

3.1 Population levels

The literature does not specifically elaborate on the effect the size of the population has on road fatalities. However, common sense would render that a larger number of people would increase the fatality risk and a population of zero would never see a road fatality. Due to the lack of literature, the authors opted to prove this notion, using the population and absolute fatalities in the US. For 2015, the correlation between the population in the various US states and the number of road fatalities was 0.9187. Clearly, population size and road fatalities have a significant and positive relationship.



GA=Gauteng, KZ=KwaZulu Natal, WC=Western Cape, EC=Eastern Cape, FS=Free State, MP=Mpumalanga, LI=Limpopo, NC=Northern Cape', RSA=Republic of South Africa

Figure 2: Road Fatality and Population Changes (2005-2015; %)

Source: RTMC, 2006-2016, Statistics SA, 2015

In South Africa the population grew by +12.7% during the 2005-2015 period, while the road fatality rate decreased by 8.4%. For the various South African Provinces, the relationship between population growth and road fatality rates varies, as can be seen in Figure 2. All provinces see a growth in population during the 2005-2015 period. The Free State has the smallest population growth of only 2.6%, while the Gauteng province has the largest growth (17.1%). Fatality rates for most provinces have reduced, while the Eastern Cape, Limpopo and the Northern Cape recorded an increase in the fatality rate. These findings, therefore, conclude that population levels, on its own, do not explain road fatality trends for South African provinces.

3.2 Gross Domestic Product

Increased levels of economic prosperity lead to an increase in mobility, vehicle ownership and, generally, to an increased road fatality risk. The analysis of economic downturns, such as the economic recession of the early eighties, show reversed trends. Wagenaar (1984) established a significant concurrent inverse relationship between the rate of unemployment and the frequency of crash involvement. However, he found a one-year lagged effect between these two variables. Hedlund et al. found that the 1982 changes in US based road traffic fatalities were due to demographic shifts, economic conditions and changed travel patterns.

More recently, various studies have established a road safety risk reduction during economic downturn. Yannis et al. (2014) found a reduction in fatalities in several developed countries that cannot be justified by policy efforts alone and are partly attributed to the global economic recession affecting most countries' economy and mobility (Yanis et al., 2014). Wegman et al. (2017) established that a recession is associated with less driving among young drivers, less drinking-and-driving and less speeding. It is not clear if these changes fully explain the larger decline in the number of fatalities.

Examining the annual percentage changes in road fatality rates in various European countries and GDP per capita, Yannis et al. (2014), found a positive correlation between the annual GDP increases and annual mortality rate increases and vice versa. This pattern was verified in Greece, Spain, Italy and Portugal, as well as various Eastern European countries.

However, Kopits and Cropper (2005) identified that GDP growth follows a breaking point trend. As GDP grows, as mentioned before, the fatality rates increase. After a certain moment (breaking point), however, an increasing GDP develops a negative relationship with road fatalities. Kopits (2004), in her dissertation called ‘traffic fatalities and economic growth, proved this theory based on the data displayed in Figure 3.

Once GDP levels (per capita) are large enough, governments implement more measures to combat road fatalities (such as increased spending on road maintenance and emergency services, amongst others). Furthermore, individuals can afford vehicles with more road safety features.

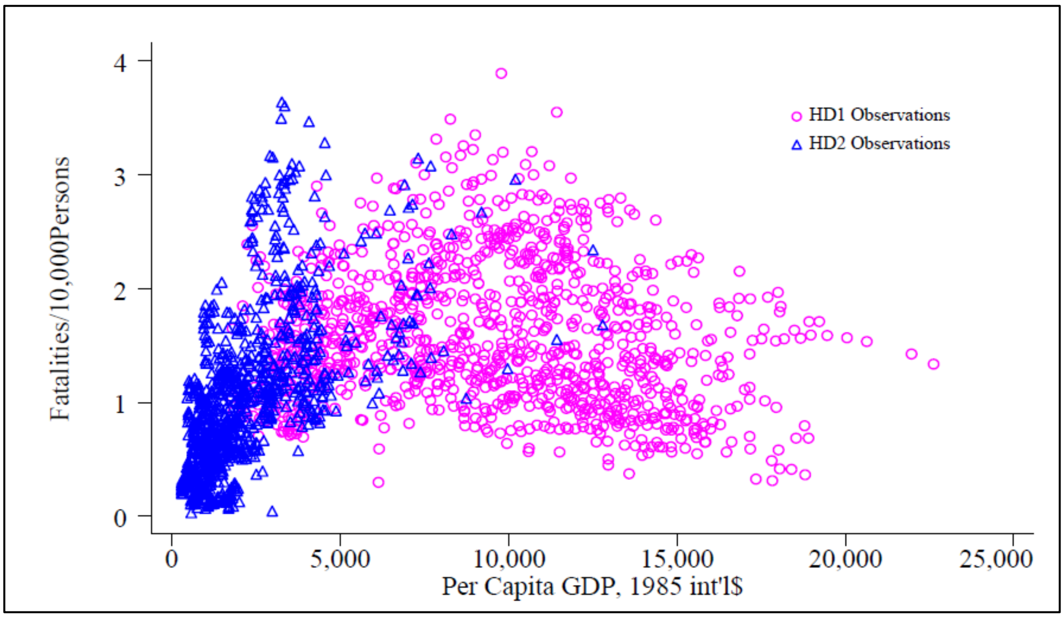


Figure 3: GDP per Capita Versus Road Fatalities/10 000 Population (1663-1999)
Source: Kopits, 2004

Between 2005 and 2013[1], the GDP for South Africa more than doubled (+115%). Economically, all provinces have seen a substantial increase in absolute GDP of at least 100% between 2005 and 2013 (see Figure 4).

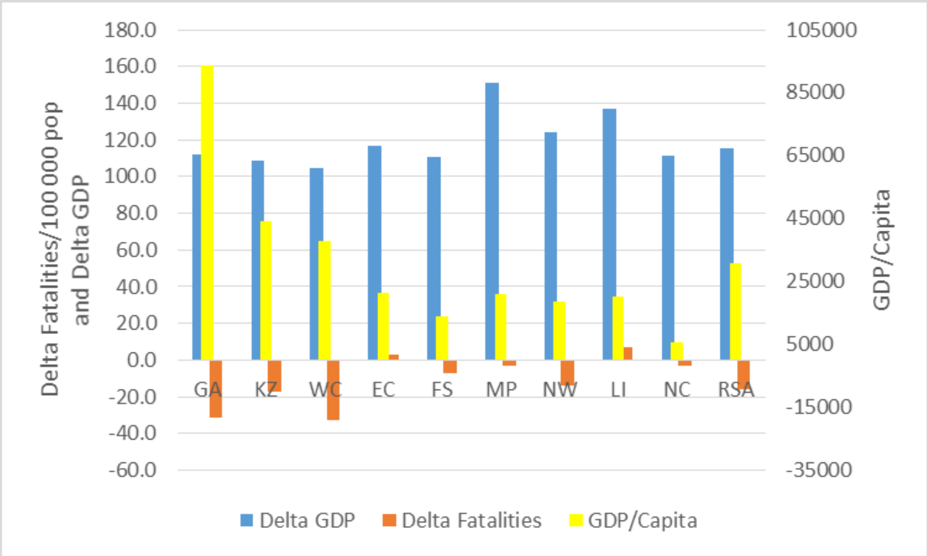


Figure 4: Fatalities/100 000 Pop, GDP (2005-2013) and GDP/Capita (2013)

Source: RTMC, 2006-2016, Statistics SA, 2014 & 2015, UN-Habitat, 2008

Only Gauteng, KwaZulu Natal and the Western Cape have been reducing fatality rates to levels below 20 per 100 000 population. The change in GDP per province does not explain the differences between the provinces. Nonetheless, when comparing the fatalities to the GDP per capita, there are substantial differences between the various provinces whereby the three provinces that lead the decreasing trend all have GDPs per capita that are significantly higher than the other provinces. Based on the international literature, this relation would be expected, since provinces with comparatively higher GDP have implemented far more measures to combat the road safety burden than the provinces that are lagging behind. It can also be postulated that the break point, in terms of GDP growth and road accident numbers, has been reached in the provinces with higher per capita GDP growth.

3.3 Motorisation

Vehicle fleet size and composition have been identified in the literature as factors influencing road fatality levels. Like GDP, motorisation levels, based on broken-line regression models for Austria, Belgium, Greece, Hungary, and The Netherlands, also show the simple pattern of an increasing trend until a maximum breaking point is reached and a downward trend starts (Yannis et al., 2011; Oguchi, 2016). It was found that different countries reached specific motorisation rates at different (and sometimes distant) moments in time (temporal landmarks). Some of those countries exhibit a breakpoint within a narrow range of motorisation rate values, implying perhaps similar social and economic conditions and/or similar road safety culture, while different ranges were observed for countries with larger variation in their geographic and socio-economic context (Yannis et al., 2011). Based on a piece-wise linear regression model analysis of accident trends in European countries, results suggested that the maximum fatality rates experienced (i.e. the breaking point) in various countries, over time, lies within a relatively short range of vehicle ownership, namely around 200 to 300 vehicles per 1 000 inhabitants (Yannis et al., 2011).

As indicated by Yannis et al., 2011; Yannis et al., 2014), internationally, the fatality trend per vehicle ownership changes between 200 and 300 vehicles per 1000 population. At the lower levels, an increase in vehicle ownership results in an increase in road fatalities, while this trend is reversed at the higher levels (from around 200 vehicles per 1 000 population).

Vehicle ownership per 1 000 population is very different in the various South African provinces. Where the average vehicle ownership level in South Africa is just over 200 vehicles per 1 000 population in 2015, in Gauteng and the Western Cape, the levels in 2015 are more than 250 vehicles per 1 000 population in the whole period (2005-2015). These are, therefore, provinces where the breaking point could have been surpassed already. The vehicle ownership in other South African provinces is well below 200 vehicles per 1 000 population, on average, over the whole period (2005-2015).

The question arises whether South Africa, on a provincial basis, follows international trends regarding vehicle ownership per 1 000 population. It was decided to use the vehicle ownership per 1 000 population information for 2010, as this falls in the middle of the research period (see Figure 5).

There are two provinces that have vehicle ownership rates below 100 per 1 000 population, i.e. the Eastern Cape and Limpopo. These provinces still show an increase in road fatalities between 2005 and 2015. The other province that still displays increasing road fatalities between 2005 and 2015 is the Northern Cape, having just under 200 vehicles per 1 000 population.

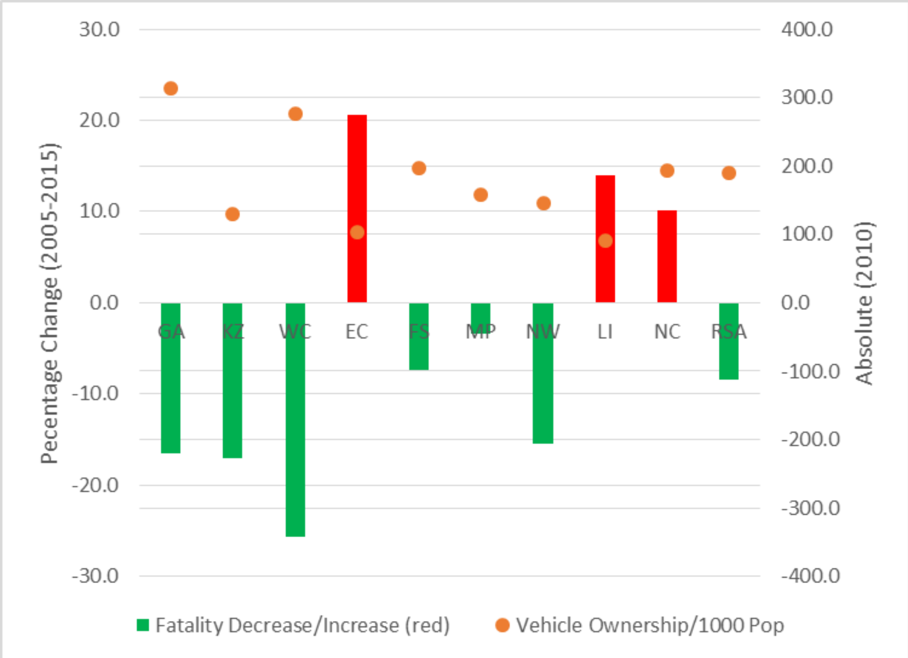


Figure 5: Road Fatality (2005-2015; %) and Vehicle Ownership (2010; abs)

Source: RTMC, 2006-2016, Statistics SA, 2015

Overall, it can be concluded that population, GDP and motorisation have all increased significantly over the years, while the fatality rates have decreased. From these results, the question arises: has the economic development in the country hit a level where fatalities have peaked and the relationship between economic growth and road fatality rates is now negative? Based on the previous analysis, it can be concluded that this is, most likely, the case for six of the nine provinces.

4 MEASURES FOR HAZARDOUS LOCATIONS IN THE WESTERN CAPE

The Western Cape has been making a real effort to combat the road safety burden over the past decade, implementing many measures in the enforcement spheres. However, the reduction in fatalities has stagnated, leading to the realisation that more needs to be done. During the development of a recent ‘Road Safety Implementation Plan’ it was concluded that improving hazardous locations has led to a substantial drop in fatalities, internationally. A strategy was, therefore, developed to identify the top ten hazardous locations in the different districts in the province. A Geographic Information System was used for the location identification.

4.1 Hazardous Location Identification

The research team used the ‘fishnet’ function in GIS to combine fatalities that occurred within a particular cell. The fishnet function creates a feature class containing a net of rectangular cells. Creating a fishnet requires two basic sets of information: the *spatial extent* of the fishnet and the *area boundary* for the fishnet.

Given the size of the database, it was necessary to utilise the six districts as the area boundaries, rather than carry out one single analysis for the whole Province. For the size of the rectangular cells in this analysis, the team chose a 100m by 100m area based on a previous study by Elvik (2007), who found that various countries use a similar approach. This size would guarantee that intersections would be identified and not combined with too much of the links in the road network.

The analysis, using data from 2011 to 2015 as location identification, was deemed reliable in that period. The GIS coded iPAS data, unfortunately, did have missing data. However, as this is the most reliable data available in the province, this shortcoming had to be tolerated. Locations were ranked based on fatality numbers. Internationally, this has proven to be acceptable in cases where fatality numbers are high, which is still the case in the province. When crash numbers reduce, countries often move to a ‘weighted sum’ approach (Elvik, 2007). As an example, the top ten locations for the West Coast District are displayed in Figure 6.

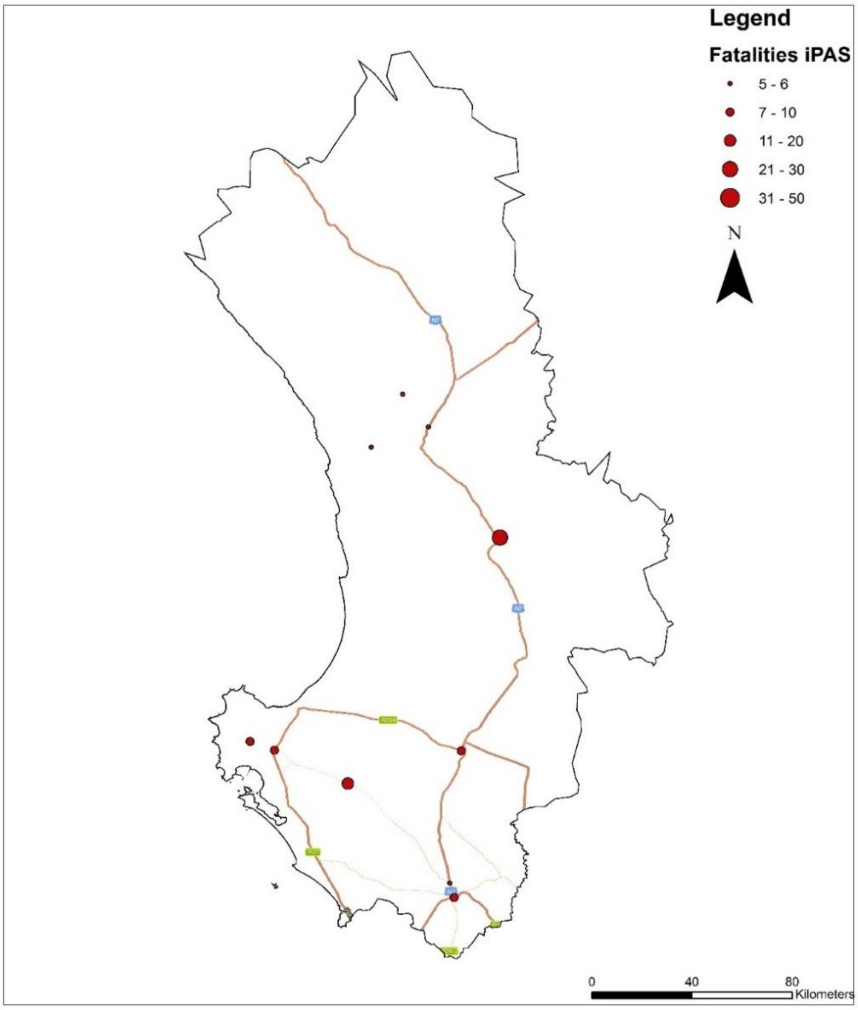


Figure 6: Top Ten Hazardous Locations in the West Coast

Once the most hazardous locations were identified, a review of the locations was carried out using Google Street View (The authors are aware that there is a risk that the infrastructure at locations could have changed since Google Street Maps collected its data. However, as Google Street Maps is supposed to update every 6 months, this risk is limited).

4.2 Measure Identification

The identification of appropriate measures depends on the location and the crash data collected. The required measures vary substantially between a location with high numbers of non-motorised transport fatalities and high numbers of fatalities, due to risky driver behaviour. In the first instance, measures, such as suggesting land-use changes and the implementation of traffic calming measures, are most likely to combat the risk, while in the second examples, driver education and law enforcement are more promising.

Figure 7 provides a comprehensive flow diagram of potential crash data and the types of measures that are most likely to reduce the road safety risk. The measures in Figure 7 do not provide detailed guidance to the districts yet. The project team developed warrants that provide further guidance to the districts (see, for instance, Vanderschuren et al, 2017). Table 1 provides a sample of the type of warrants. Unfortunately, limited space prohibits the inclusion of the full table in this paper. The sample provides the information for locations where improved delineation is required.

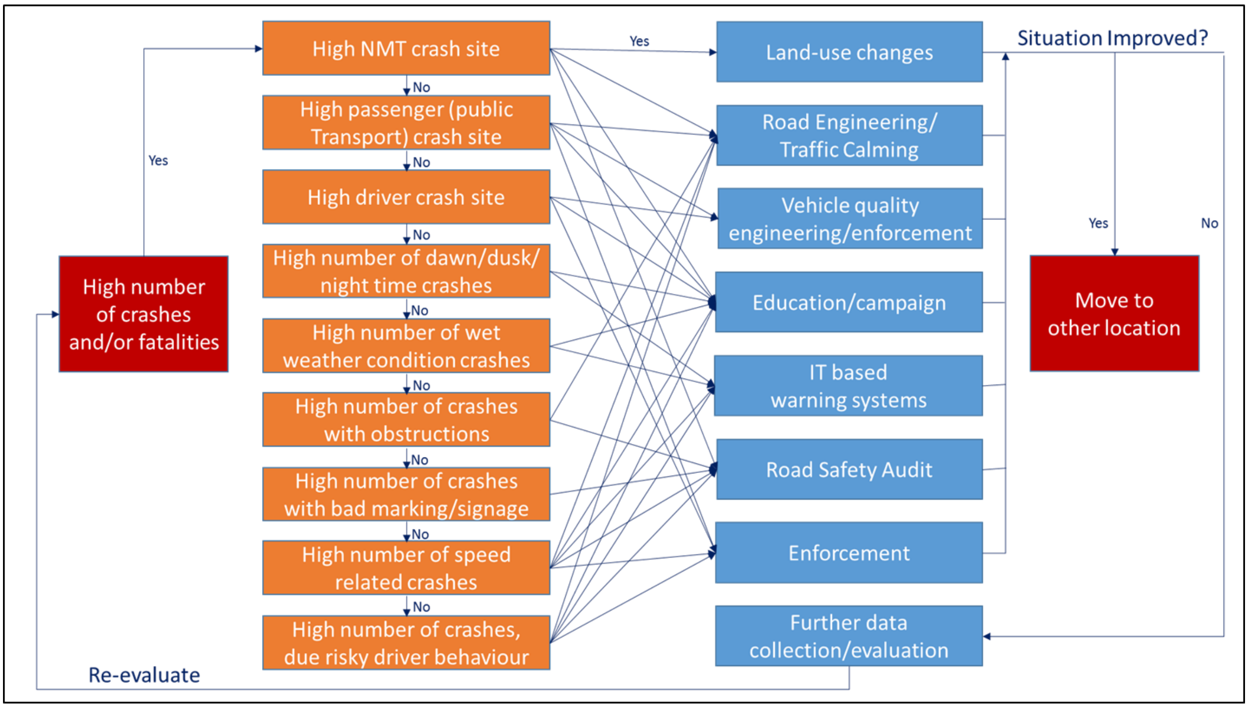


Figure 7: Identification of Road Safety Measures for Hazardous Locations

Table 1: Sample of Warrant Description

Intervention	Example	Warranted Along	Measure to Prevent
Delineation: Delineation is the pavement marking, guideposts, and raised pavement markers used on, and adjacent to, the roadway to define and communicate vehicle travel paths for motorist. Centre and edge delineation treatments help drivers judge their position on the road and provide advice about conditions ahead. **Types of delineation treatments**: • Line Marking - Painted line marking, Rumble strips; • Retroreflective Pavement Markers (RRPMs) - ‘’Cat eyes’’ • Guide posts - 1 metre high reflective posts; • Chevron Alignment markers (CAMs); • Warning signs and Advisory speed signs. Advisory signs tell drivers how to navigate the hazard safely.		• All roads to assist motorists to judge the alignment of the road, see their dedicated lanes and discourage them from overtaking and accidental drifting from high speed or driver fatigue; • Delineation treatments are particularly helpful where there is poor visibility (for example, due to rain, fog or darkness) and on sharp bends; • Roadways with a change in alignment e.g. sharp bends, at night and in rainy weather; • Where road alignment guidance is required to navigate the horizontal and vertical curves; • Roads with road hazards to inform drivers of the nature of the hazard they are approaching.	Run-off Road

Source: Vanderschuren et al., 2017

5 CONCLUSION AND RECOMMENDATIONS

Road fatalities remain a burden for countries, provinces and cities around the world. South Africa’s road safety rate is worse than the Global and African average, at 31.9 fatalities per 100 000 population (Peden et al., 2013). For the various South African provinces, the (uncorrected) fatality rates range between 18.9 fatalities per 100 000 population (Gauteng) and 33.8 fatalities per 100 000 population (Free State). Between 2005 and 2015, the total road fatality rates in South Africa decreased by 8.4%. However, the decrease was not common for all provinces with six (out of nine) provinces recording a decrease of between 3.5% in Mpumalanga and 25.7% in the Western Cape. Alternatively, in the Northern Cape (10.2%), Limpopo (14.0%) and the Eastern Cape (20.6%), road fatalities increased during the same period.

The analysis in this paper found that, in South Africa, road fatalities have decreased over the past years while the population, GDP, GDP per capita and motorisation rates have increased. This finding suggests that South Africa has surpassed the breakpoint, where a positive relationship between external factors and road fatalities turns into a negative relationship. However, looking at the provincial data, this might not yet be the situation in all cases. In the literature (see, for instance, Yannis et al., 2011) it was established that the breakpoint for motorisation is between 200 and 300 vehicles. Most South African provinces have motorisation levels of (close to) 200 vehicles per 1 000 population or more. Two of the three provinces that have lower motorisation rates still display increasing fatality levels. The one province that is the exception is KwaZulu Natal which, most probably, is improving, due to the fact that it has a large city (high densities), i.e. Durban.

Despite the decreasing road fatalities being the best performing province in terms of road safety management in South Africa, the Western Cape still needs to find ways to reduce road fatality rates. Following international best practices, the 'fishnet' method was used to identify the top ten hazardous locations. This was complimented by the analysis of local crash types and a review of the location using Google Street View. Combined with the warrants provided in this study, the districts have all information required to reduce fatality rates at the top hazardous locations.

The authors conclude that great improvements in road safety in South Africa are required. A pathway to achieve this would be to identify the top ten hazardous locations in all districts. Whilst most provinces are still playing catch up, the best achievers (Gauteng and the Western Cape) still need to continue the implementation of road safety measures to improve their records, as these rates are still well above the global average. It should be borne in mind that local factors can significantly impact the best road safety management measures, to be applied in that province and, consequently, the road safety gains that can be achieved. In other words, each province will require a tailor-made approach to improve its road safety levels.

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