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Combatting the Road Safety Burden in the Developing World: The Case of South Africa

Marianne Vanderschuren[a]*, Melvin Arendse[b],
Tanya Lane-Visser[a] and Aliasgher Janmohammed[a]

[a]*University of Cape Town, Centre for Transport Studies, Private Bag X3, Rondebosch, South Africa*
[b]*Western Cape Government, Transport and Public Works, 11 Leeuwen Street, Cape Town, South Africa*

Abstract

An estimated 1.25 million people died globally, as a result of road traffic crashes, in 2013 (WHO, 2015). The majority of these deaths occur in low- and middle-income countries (Peden et al., 2004). Low-income countries have fatality rates that are more than double than those in high-income countries (WHO, 2015) and, although global fatalities have plateaued since 2007, the fatalities in low- and middle-income countries are still increasing. According to Perel et al. (2007), road safety in low- and middle-income countries is a neglected research area. This paper aims to assist in closing this research gap. The paper starts with an international road safety comparison on a per country level, followed by a more detailed analysis of different South African provinces. All provinces have shown an increase in population, while six out of nine provinces have absolute and relative (per 100 000 population) reductions in road fatalities between 2005 and 2015. Focusing on the province that reduced road fatalities most, i.e. the Western Cape, road safety measures were proposed and scenario calculations carried out. The results provide valuable insights regarding the road safety status-quo in South Africa and identifies the most cost-effective road safety measures for the Western Cape Province, going forward.

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Keywords: Road Safety, Africa, South Africa, Road Safety Scenarios, Cost Effective Road Safety Measures

1. Introduction

Road fatalities were already labelled an epidemic in 1973 (British Medical Journal, 1973). Road fatalities and injuries have claimed a total of over 30 million lives worldwide (NGO Brussels Declaration, 2009) with at least 150 road fatalities occurring every hour of every day, totaling 1.25 million people globally per annum (WHO, 2015).

There is a significant difference in the number of fatalities per population when comparing high-income countries to low- and middle-income countries, with the former having almost 2.5 times fewer fatalities than the latter (Wegman, 2017). In 2013, the WHO studied overall road safety in several countries in the African region. These countries showed an average road fatality risk that is well above the global average, i.e. 24.1 casualties per 100 000 population in Africa, compared to 17.0 casualties per 100 000 population globally.

North America and Europe score well below the global average road fatality rates, while Africa has the worst overall road fatality rate when comparing continents (see Fig. 1). African countries, included in the comparison, all

* Marianne Vanderschuren. Tel.: +27-21-650-2593.
E-mail address: Marianne.vanderschuren@uct.ac.za

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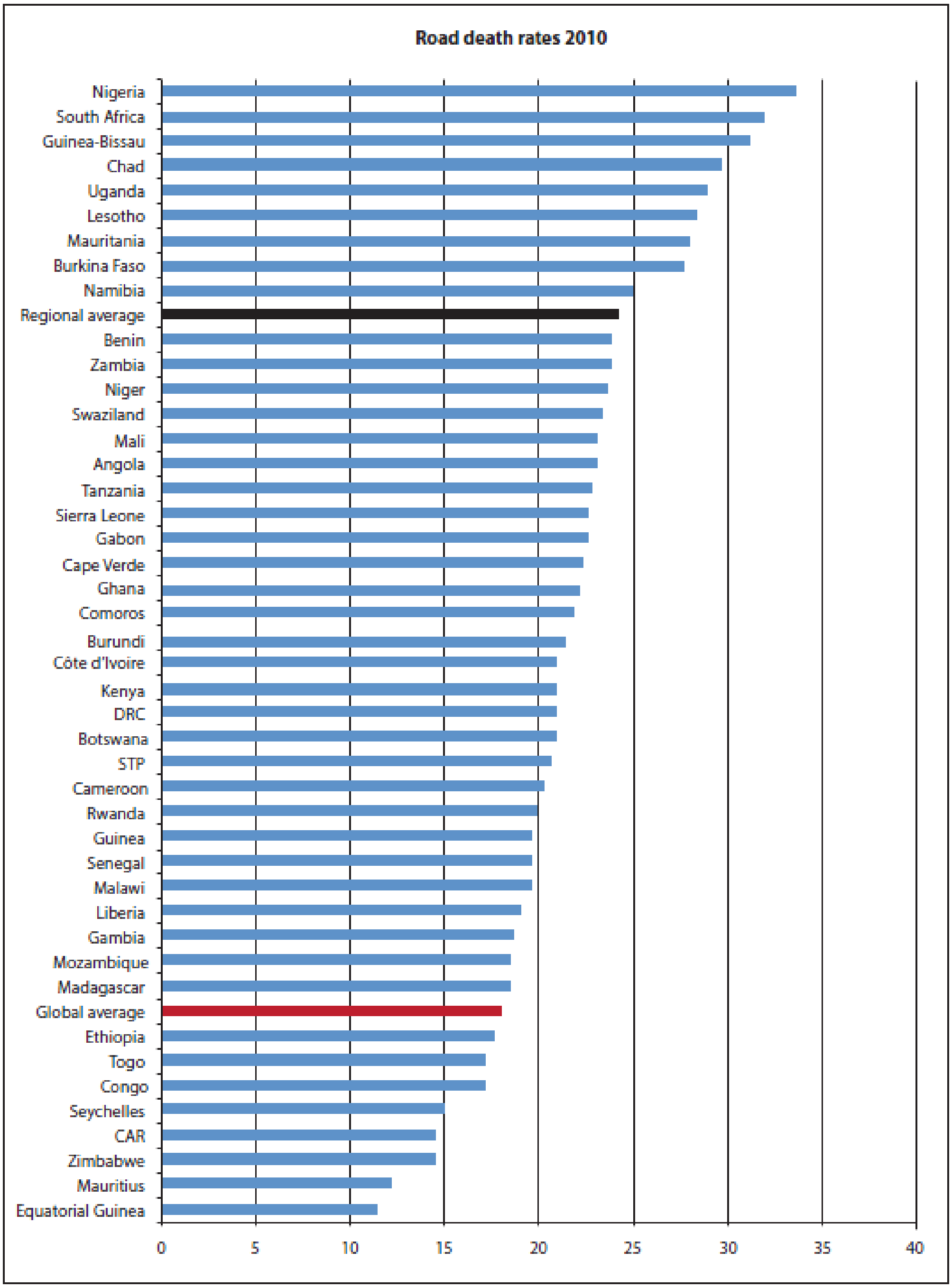
have an overall road fatality risk that is substantially higher than the global road fatality risk. It can be concluded that South Africa's road fatality rate is among the worst in the world. Given the severe road safety burden on the African continent and in South Africa, this paper aims to address the road safety knowledge gap in South Africa by analyzing the state of road safety in the country and by identifying the most cost-effective management interventions to improve road safety.



CAR = Central African Republic; DRC = Democratic Republic of Congo; STP = Sao Tome & Principe.

Fig. 1. Road Fatality Rates in Africa (per 100 000 inhabitants) in 2010 (Peden et al., 2013).

2. Methodology

Based on a literature review and available data, a provincial comparison of the status of road safety in South Africa was conducted. South African road fatality information was based on Road Traffic Management Corporation (RTMC) annual reports. Population data was collected from Statistics South Africa (STATSSA).

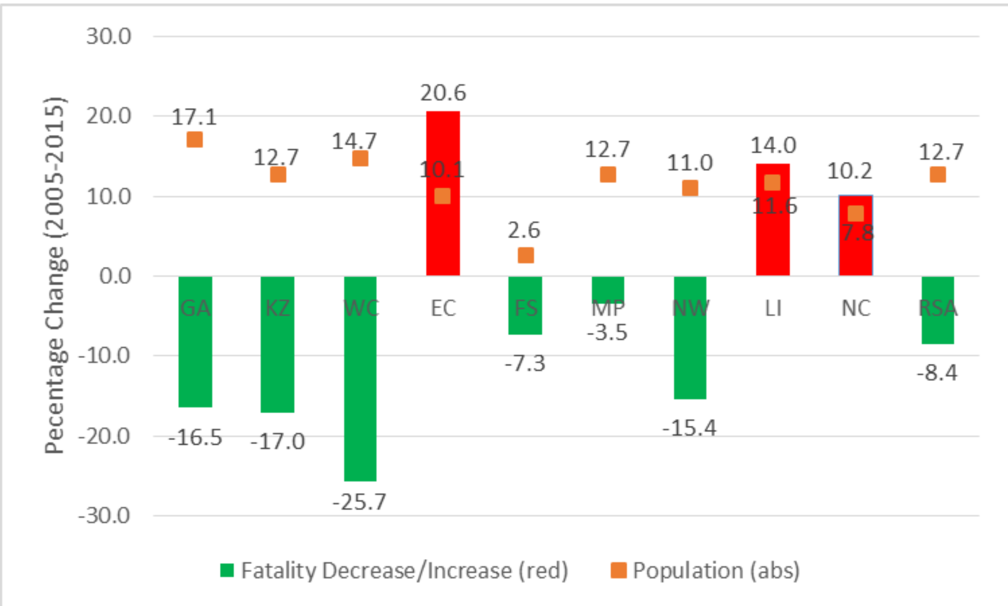
Detailed information for one of the provinces, namely the Western Cape, and an additional literature review was then used to identify cost effective road safety management measures and their implementation profiles. Besides the above-mentioned databases, provincial information from the intelligent Provincial Accident System (iPAS) and the provincial Forensic Pathology System (FPS) was utilized.

Geo-coded information from iPAS and information on the road safety measures, identified during the literature review, were combined to establish the potential costs and benefits of various road safety management scenarios within the province. A total of nine cost effective scenarios were identified. The Benefit Cost Ratio (BCR) and break-even point for a conservative and optimistic uptake of the measure, pertinent to each scenario, was calculated and conclusions and recommendations were drawn based on the analyzes.

3. Road Fatalities and Population in South Africa

For the nine South African provinces the change in fatalities, compared to the change in population, were analyzed. Overall, the South African population grew by 12.7% during the 2005-2015 period, while the road fatality rate decreased by 8.4%, which is encouraging. However, differences between provinces are vast (see Fig. 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%). During the 2005-2015 period, the total road fatality rates in South Africa decreased by 8.4%, as mentioned. Most provinces also witnessed a decrease of between 3.5% in Mpumalanga and 25.7% in the Western Cape. However, the Northern Cape (10.2%), Limpopo (14.0%) and the Eastern Cape (20.6%), the most rural provinces, saw an increase in road fatalities.



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

Fig. 2. Road Fatality and Population Changes Between 2005-2015 in Percentages (RTMC Annual Reports and STASSA).

As can be seen from the WHO analysis in the introduction, in health research, (road) fatality analysis is conducted through the analysis of fatalities per 100 000 population. Based on the RTMC annual reports and STATSSA population information, it is possible to calculate the road fatality rates per 100 000 population. Table 1 provides an overview of the change in road fatality rates per province, between 2005 and 2015. The reader needs to note that the numbers in Table 1 cannot be directly compared to the numbers in Fig. 1, as there is a difference in definition and data accuracy.

Table 1. Road Fatality per 100 000 Population for South African Provinces (2005-2015)

Year	**GP**	**KZ**	**WC**	**EC**	**FS**	**MP**	**NW**	**LI**	**NC**	**RSA**
2005	26	30	30	22	37	39	35	26	32	29
2006	30	30	30	28	43	39	37	25	36	31
2007	28	25	30	26	41	46	37	26	33	30
2008	22	27	27	23	32	47	34	26	29	28
2009	21	28	23	24	35	42	33	28	30	27
2010	18	27	23	27	42	40	33	28	39	27
2011	22	27	20	25	37	40	29	31	26	27
2012	19	25	20	24	37	36	32	31	36	26
2013	16	25	18	21	19	34	27	25	29	22
2014	19	25	19	21	31	32	27	24	35	24
2015	19	22	19	24	34	33	27	27	33	24

Interestingly, provinces that had an increase in absolute fatality rates (see Fig. 2), also had an increase in fatality rates per 100 000 population, while the same positive correlation is true for the provinces that had road safety improvements. However, there are interesting differences between the absolute and relative changes over the analysis period (2005-2015). Both Limpopo and the Northern Cape have had a minor increase in relative fatality rates of around 3%, while the relative increase per 100 000 population in the Eastern Cape was 9%. Improvements in relative fatality rates range from 8% in the Free State, 15% in Mpumalanga, 23% in the North West, 27% in KwaZulu Natal and Gauteng, to 36% in the Western Cape.

There are clear differences between the absolute and relative road fatality rates, looking at Table 1 and Fig. 1. This is an indication that it is important, when identifying road safety measures, to analyze, both, the absolute and relative data.

Given the success in reducing absolute and relative road fatality rates and the fact that more detailed data is available, the remainder of this paper will unpack the data for the Western Cape. A first step is comparing absolute and relative fatalities for the various Transport Analyzes Zones (TAZs) in the Western Cape (see Fig. 3).

When analyzing Fig. 3, the main areas of concern are areas above the Global and African average lines (indicated by the symbols G and A, respectively), as well as areas below, or on these lines, that have very high Average Annual Fatalities (AAF). Khayalitsha and Philippi fall in this latter category. Even though the average fatalities per 100 000 population is not high, the absolute number of fatalities is. Pedestrian fatalities account for around 80% of all fatalities in these areas. Leeu Gamka, Laingsburg, Touwsriver, De Doorns, Maitland, Durbanville, Beaufort West, Bellville and Nyanga have worryingly high fatality rates per 100 000 population.

Leeu Gamka is a town of less than 3 000 residents along the N1 (a major highway running across South Africa), where many long-distance minibus taxis cause passenger fatalities. Laingsburg, Touwsriver, Durbanville, Beaufort West and Bellville are also located along the N1, and have similar issues. In De Doorns, informal traders encroach into the road reserve of the N1, creating severe conflicts, while Nyanga, Maitland, Khayalitsha and Philippi encounter many conflicts with non-motorized transport on high speed arterials. This is, predominantly, due to land-use and transport conflicts and a lack of non-motorized transport facilities in these areas.

Although the fatalities in these TAZs along the N1 are not residents, the data does indicate that further investigation into the road safety situation in these towns is required.

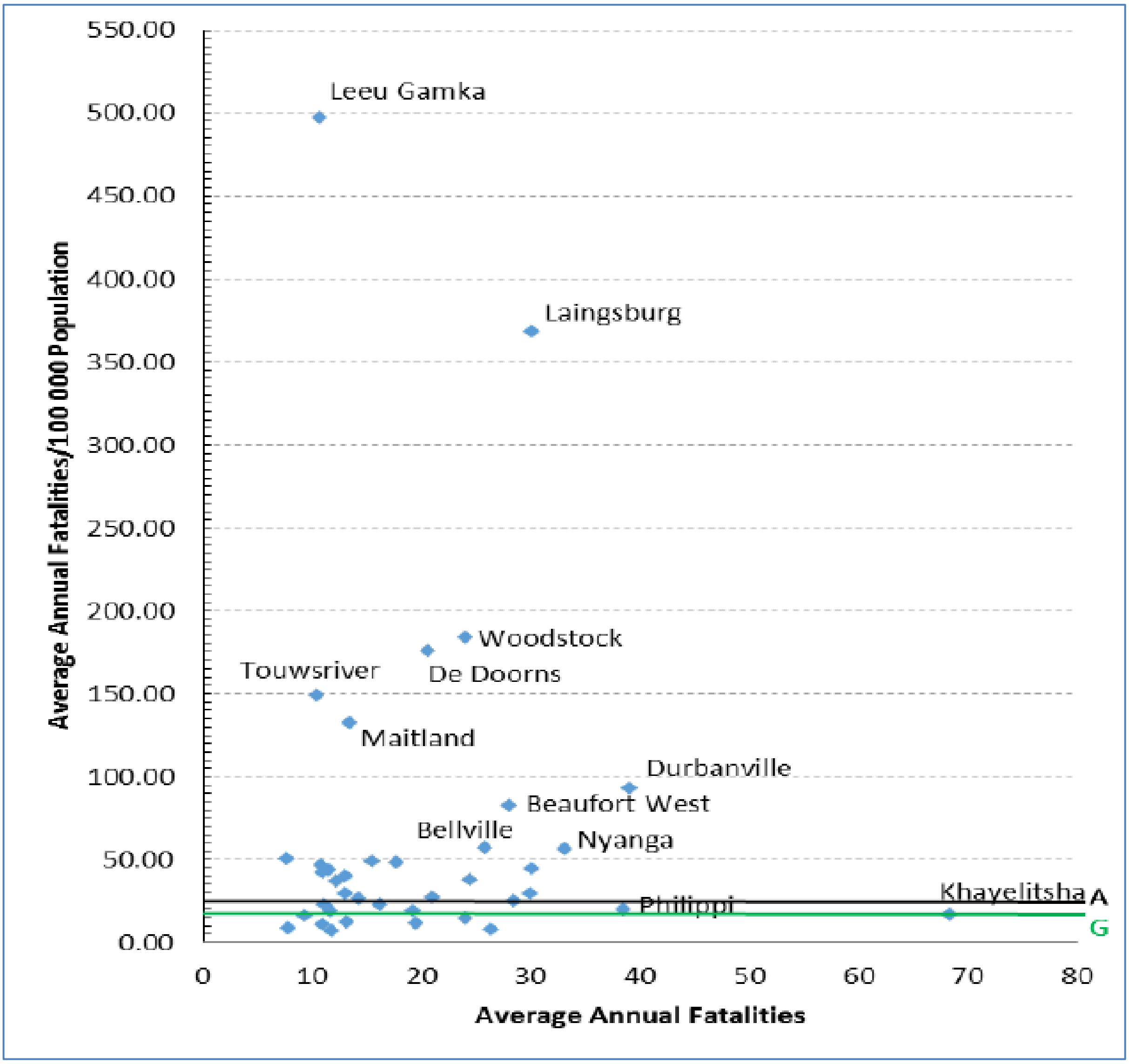


Fig. 3. Average Annual Fatality versus Average Annual Fatalities per 100 000 Population Between 2011-2015 (iPAS and STASSA).

4. Road Safety Measure Analysis for the Western Cape

The Western Cape clearly has improved road safety within the province over the past decade. However, fatality rates are still higher than the global average, and not approaching the Vision Zero that was adopted in this province (WCG, 2016). Further improvements are, therefore, required. Based on a literature review (Ponnaluri, 2016; Ghislanzoni et al, 2013; Varhelyi, 2002, amongst others), the effectiveness of road safety measures, i.e. technology, enforcement, education, infrastructure and regulatory improvements, were determined. Assessing the transferability of potential measures to the Western Cape context, as well as the identification of hazardous locations where these measures can be applied, was an intermediate step. Based on this reduced list of viable measures, the expected effectiveness of said measures could be calculated in more detail.

The following measures were identified as viable candidates for application in the Western Cape:

- Intersection treatment, through the application of a **roundabout**. Due to potentially different level of impacts, this measure was calculated for both a low-density (Prince Alfred Hamlet) and a high-density (Khayelitsha) scenario. Intersections are assumed to require changes to a 100 by 100-meter area.
- Speed reduction on a highway to be achieved through the implementation of **rumble strips** or variable message signs (repeated over a 14-kilometre stretch of road adjacent to Grabouw).
- Vision improvement through the implementation of street **lighting** reduces the crash risk and crash severity. For this scenario, a rural intersection near Rawsonville was selected. In total, 15 lampposts are suggested. Determination of the type and level of lighting, as researched by Jackett and Frith (2013), was not included in this study and will need to be explored in future research.
- A part of the National Road between Cape Town and Johannesburg (N1) was identified as severely risky, due to long distance paratransit crashes. The fatalities per 100 000 inhabitants for the small village of Leeu Gamka (approx. 2 750 inhabitants) approaches 500 per annum. The implementation of **speed-over-distance** enforcement is suggested.
- Educating the general population about road safety risks is another identified measure. The scenario here includes province-wide **campaigns**.
- Improved emergency services can be provided by increasing the number of **ambulances**, deploying paramedics on **motorcycles,** or the provision of **helicopter**-based services. All three options were calculated as separate scenarios on a provincial scale.

The cost effectiveness of each of these measures and applications were compared through a CBA approach.

4.1. The Value of a Life in the Western Cape

When conducting a CBA, all costs and benefits are converted to a monetary value; in this case expressed with South African Rand (ZAR) as the currency (R1 = US$0.074 as of July 2018). In the context of this study, benefits are embodied in the form of fatalities avoided. To be able to monetize the benefits, the value of a human life had to be determined. It was important to ask whether all lives should be valued equally. In practice, it is known that this is not the case. One such indicator is the value at which a person insures his/her life (using the willingness-to-pay principle), which is not equal for everybody. Another common way to establish the value of a life is by calculating the earning potential of an individual. However, this discriminates against the poor and old. Sund (2010) confirms that putting a monetary value on a life is a sensitive aspect, in many cultures and religions around the world, but that the allocation of scarce resources to save lives needs to take precedence over the ethical concerns.

The literature review conducted highlighted a number of ways to estimate road traffic crash costs, but there seems to be little consensus regarding the ‘best’ method. Most of the methodologies are data dependent and the use of specific methodologies is mainly attributable to the level to which useable data is available for some road traffic crash cost components (Wijnen, 2013). Internationally, the willingness-to-pay approach is generally regarded as the correct method from a theoretical point of view, however, collecting reliable data has been proven to be very difficult and costly, especially in developing countries (Mohan, 2002; Donário and dos Santos, 2000). Furthermore, using a varying amount for different people is socially an unacceptable concept, especially in a developing world context. According to the South African Constitution, people are all equally important and protected under the law. From that point of view, the value of a life should be the same for all South Africans. This approach was adopted in this study.

The question still remains: what is the value of a life? Within the South African literature, varying valuations of life has led to fluctuating overall road crash cost estimates. Various methodologies were reviewed, and it was concluded that the method established by the Council for Scientific and Industrial Research (CSIR) and the Road Traffic Management Corporation (RTMC, 2016) was the most academically sound approach currently available in the South African context.

Based on 2015 cost values, the following values for a fatal, injury or damage only crash, respectively, were established (RTMC, 2016):

- the cost per road traffic fatality was R5 435 261,

- the cost for a major injury, due to a road traffic crash was R765 664,
- the cost for a minor injury, due to a road traffic crash was R152 244, and
- the cost for a damage only road traffic crash was R48 533.

If all crash related data were available and reliable, this information could be used to establish the overall benefits of reducing road traffic crashes. However, the most reliable data is available for fatalities only. Reliability reduces rapidly when looking at less severe crashes, especially the geo-coded information required to identify the scenario locations. It was, therefore, decided to only use fatal crash locations to identify locations that require road safety improvements. Nonetheless, when reducing fatalities, it is likely that crashes, in general, are reduced, which will also have a positive impact on non-fatal crashes and the costs associated with them.

Information from iPAS revealed that four in five crashes happen within the Cape Metropole. However, fatality rates in the City of Cape Town, compared to the rest of the Western Cape Province, were almost identical. Furthermore, the split between fatalities on rural roads and in small Western Cape towns is almost identical (48:52). Using this information, it was possible to establish that every fatality in Cape Town represents itself (i.e. R5.43 million) and R8.80 million of other costs, such as the costs related to hospitalization, disabilities and congestion (calculated based on iPAS data using the RTMC (2016) cost values). On rural roads, every fatality represents itself and R2.40 million of other costs, while every fatality in a small town represents itself, as well as R2.16 million of other costs.

Within the road safety scenarios, there is one exception. For improved emergency services that get more patients to trauma care facilities within the ‘Golden Hour’, it was assumed that while one fatality is reduced, a major injury is added. One potential fatality saved, therefore, accounts for a road traffic crash cost reduction of R5 435 261 - R765 664 = R4 669 597 in these scenarios.

4.2. Measure Impact Profile

The next step in the CBA was to assign an appropriate measure implementation profile to each scenario. The benefits of road safety measures do not materialize instantly, nor are they necessarily uniform. There is often a gradual improvement, until the full potential benefits are reached. The authors identified several distinct improvement profiles, which can be found in Fig. 4.

Measure A is an example where the full benefits are materialized instantly (many infrastructure measures follow this profile), and no additional benefits accrue over time. In measure B, there is a linear benefit that keeps growing year-on-year from the start of implementation (educational improvements, such as driver training, for instance, follow this profile). The profile for measure C shows an exponential improvement that plateaus (enforcement measures follow this profile), while measure D shows a slow start to the benefits, but the speed at which these benefits accrue increases (this profile is correct in theory, but it is unlikely to be applicable to road safety measures, as there is always a maximum benefit). Measures E and F (so called S-curves) are, therefore, more likely in the road safety field. The profile for measure E is applicable to road safety campaigns, while measure F is applicable when there is a negative impact during the start-up period (large construction is an example, as there is an increased risk of fatalities during construction). These profiles, thus, account for a potentially slow uptake, due to cultural and other behavioral influences.

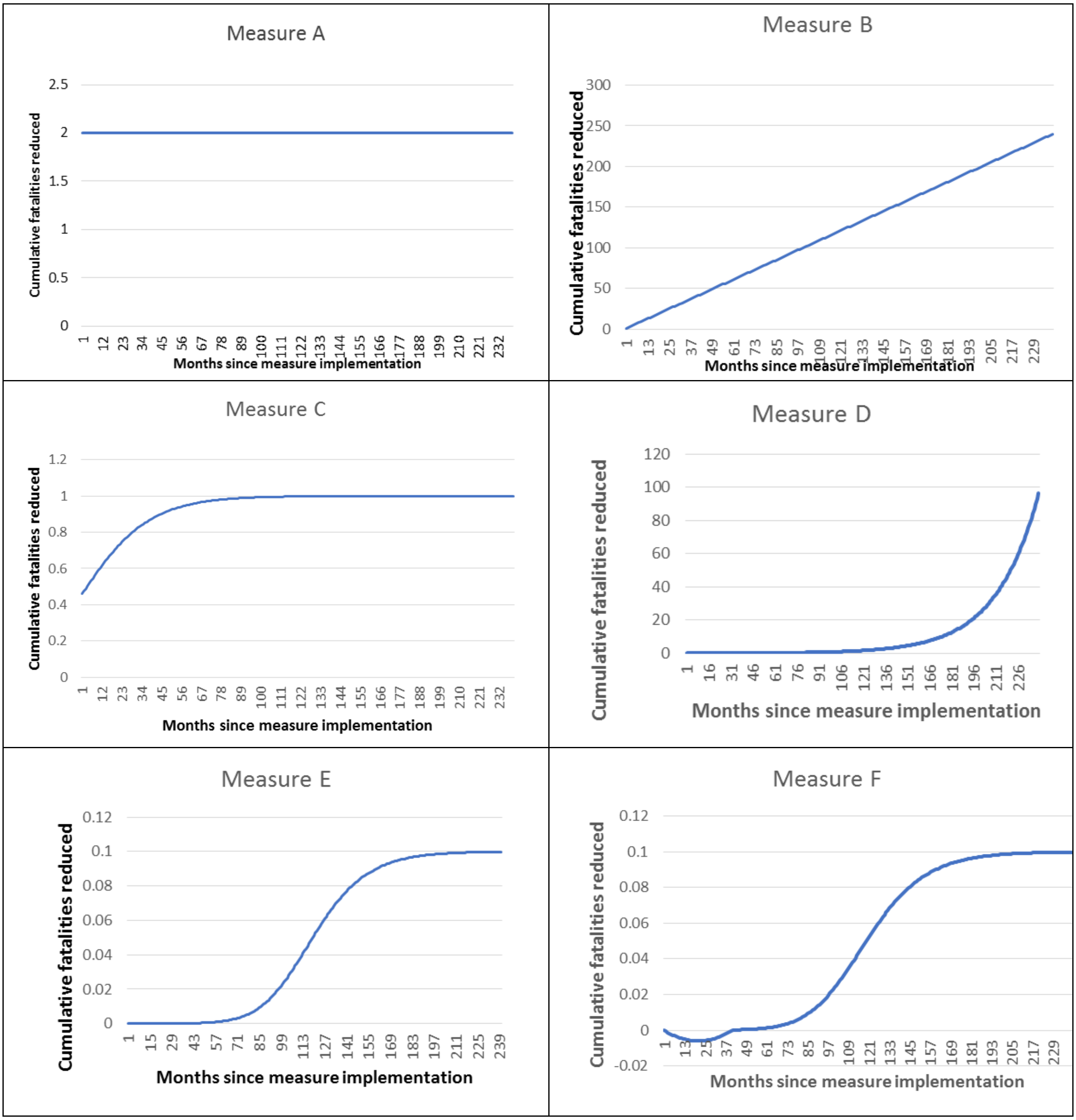


Fig. 4. Benefit Profiles for Potential Road Safety Measures.

4.3. Scenario Calculations

For each scenario, the measure impact profile selected was projected onto the fatality growth projection and an estimate of actual fatalities avoided can be obtained. Once the total number of fatalities was known, it was multiplied with the value of a human life as determined in Section 4.1. This produces a monetary value of the benefits that can be expected upon measure implementation. The costs are calculated based on the expenditures required to implement the scenario description and extrapolated over the 20-year horizon. The break-even moment (the moment when benefits are larger than the investment made and the Benefit/Cost (BC) ratio is greater than one) was also established for each scenario. Costs were based on information from one of the consultancies in South Africa that implement various roads projects.

The chosen scenarios demonstrate a wide range of options. The measures can be implemented in the area suggested, but are also applicable in other areas within the Western Cape, and possibly beyond. A detailed comparison between the scenarios modelled is provided in Table 2. No sensitivity analysis, in the traditional way, was conducted. However, to account for the discrepancies in terms of measure impact in the literature, both a conservative impact estimate (low end of the range of values published) and an optimistic estimate (high end of the range of values published) were used to calculate a conservative and an optimistic BC ratio for each scenario.

The capital investment for the scenarios ranged from R0 (campaigns and an EMS helicopter lease) to R9 million (the implementation of six roundabouts in Prince Alfred Hamlet or Khayelitsha). Operational costs varied between R1 000/annum (for the operation of lights on a rural intersection near Rawsonville) and R45.2 million (for the Educational Programme through campaigns).

The addition of an EMS helicopter also requires a large operational budget, i.e. R1.5 million lease costs per month adding up to an annually required budget of R18 million. However, in the optimistic scenario, it is expected that the addition of a helicopter saves over 7 500 lives during the 20-year lifespan of the project. The very conservative estimation shows only 215 lives saved.

Almost all scenarios have a positive impact from the start. The only exceptions were infrastructure scenarios that did have a lead time, i.e. construction did take some time and during construction the road safety risk for road users and construction workers increases (i.e. measure profile F was applied). Given that the scenario implementation was modelled for hazardous locations, it is not surprising that all BC ratios, for the 20-year period, are positive.

Of all the data shown in Table 2, the indicator that provides the most information for the decision making process is the BC ratio. The best BC ratio is recorded for rumble strips. Every Rand invested will be recovered over 2 500 times, in the optimistic scenario. The implementation of roundabouts in Khayelitsha is the second best scenario. Every Rand invested is recovered 383 times, in the optimistic scenario. The increase of EMS services through the implementation of EMS motorcycles has the next best BC ratio, where every Rand invested is recovered between 224 and over 314 times. The implementation of improved lighting also scored very well, with BC ratios between 66.9 and 267.6.

One of the questions answered by this study was: which EMS service improvement is most cost effective, when investing in EMS service gap facilities? The analysis revealed that motorcycles are most cost effective, as every Rand invested is made back between 224 and 314 times. This is much better than the other two EMS based options, i.e. additional ambulances or the addition of a helicopter.

When investing in traffic calming features, it is important to start implementation in the areas that generate the most fatalities, which can be seen when comparing the same investment in Prince Alfred Hamlet and Khayelitsha. In Khayelitsha, the investment return is 6.8 times as high.

For speed over distance, every Rand will generate a return between 21 and 28.5 times. Every Rand spent on campaigns is made back over 15 times. Given that speed over distance and campaigns affect a substantial number of people, they will contribute significantly to the overall aim of lowering the overall number of road fatalities

The break-even values in Table 2 represent the number of months before break-even is achieved. Regarding the break-even calculation, it is clear that EMS improvement bears fruit fast, i.e. within one month of implementation, assuming a homogeneous distribution of fatalities over the year. Infrastructure implementation, generally, requires a long time before benefits outweigh investments (i.e. break-even). Enforcement and education break-even faster than infrastructure investment, but not as fast as EMS services.

Table 2. Summary of Road Safety Scenario Calculations for the Western Cape

Name of Scenario:	Costs (R million)		Lives saved/20 years		Overall BC Ratio/20 years		Break-Even (fatalities only)	
	Capital/20 year	Operational/year	Conservative	Optimistic	Conservative	Optimistic	Conservative	Optimistic
Infrastructure based scenarios								
Prince Alfred Hamlet	9	0.0868	16.0	79.1	11.3	56.0	60 (67)	2 (29)
Khayelitsha	9	0.0868	58.4	288.9	41.3	383.2	44 (49)	28 (29)
Rumble strips in Grabouw	0.784	0.014	286.8	371.8	2113	2738	3 (4)	3 (3)
Lighting at the intersection in Rawsonville	0.135	0.001	4	16	202.9	811.5	26 (31)	13 (16)
Enforcement based scenarios								
Speed over distance in Leeu Gamka	2.1	1.0	59.13	80.41	21.0	28.5	15 (17)	14 (16)
Education based scenarios								
Campaigns	0	45.2	1238.4		15.1		19 (21)	
Emergence Medical Services based scenarios								
Improved ambulance services	1.8	0.495	200	300	67	101	1 (1)	1 (1)
Improved motorcycle services	0.6	0.145	200	280	224	314	1 (1)	1 (1)
Improved helicopter services	0	18.0	215	7648	4.7	166	1 (1)	1 (1)
All costings are based on base year values. No inflation on costs or benefits have been included								

5. Conclusions 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 absolute road fatalities 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.

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. The effectiveness of specific measures were compared through combining a scenario approach with the CBA method. When taking the required investments and operational costs into account, it appears that rumble strips, improved lighting and the implementation of motorcycle-based emergency services are the most promising, cost effective road safety measures to be implemented in the province.

The authors conclude that great improvements in road safety in South Africa are required. A pathway to achieve this would be for the worst performing provinces to start emulating the road safety management practices of Gauteng and the Western Cape. Whilst the majority of provinces still have to catch up, the best achievers should still continue to improve their status, as there is still a lot of room for improvement to catch up with international best practice. It should, however, be borne in mind that local factors (such as the population density, motorization levels and modal split in a province) can significantly impact the optimal 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. A detailed, localized analysis of road safety measures (such as the one presented here for the Western Cape) can greatly facilitate the continued improvement of road safety per province, and for the country as a whole.

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