STRATEGIES TO REDUCE TRAFFIC ACCIDENT RATES IN DEVELOPING COUNTRIES: LESSONS LEARNED FOR ASSESSMENT AND MANAGEMENT

I. M. SCHOEMAN
Unit for Business Mathematics and Informatics,
North West University (Potchefstroom Campus),
South Africa.

ABSTRACT
Strategy formulation and approaches in assessment and management of traffic engineering challenges related to the impact of traffic accidents on road networks in developing countries is problematic. The core focus of this paper consists of research output derived from traffic accident data available in South Africa. The availability of traffic accident data will be assessed to formulate applicable intervention traffic management strategies. Furthermore, the paper will include a statistical analysis and projection of such road traffic accident data in order to derive at certain tendencies from existing realities.

From the outcome of the research lessons learned for improved traffic planning, management and formulation of intervention strategies in developing countries will be deduced. Improved traffic and transportation planning practices is a priority in developing countries and economies and will guide resilient and sustainable traffic planning in developing countries.

Keywords: traffic accident, traffic management, traffic planning, transportation planning

1 INTRODUCTION
Patel et al. [1] report that road traffic injuries (RTIs) are the eighth-leading cause of death worldwide. The Department of Transport agency in South Africa that is responsible for road safety, road traffic law enforcement and data collection and management on traffic accidents and mortality is the Road Traffic Management Corporation (RTMC) [2] (Section 22 of the RTMC Act and Treasury Regulation 28.2). Traffic data from Ref. [2] reveal that some 24 fatalities/100,000 population occur in 2015 in South Africa.

Notwithstanding the fact that Australia’s per population road death rates have declined 57.9% for the period 1975–1995 they are continuously working on their road safety. Langford & Newstead [3] report that Australia adopts a Safe System Strategy in 2003 that is similar to the one that have been implemented in Sweden and the Netherlands to support safer roads, safer speeds and safer vehicles. The outflow of this was only 5.6 fatalities per 100,000 population in 2010. In 2011, they also released a new National Road Safety Strategy which includes an update of key statistical measures. Hence, to improve road safety in developing countries, there must be on-going planning and management. This paper will guide developing countries in improving road safety by lessons learned from assessment of road safety data and in showing how to manage, analysis and predict traffic accidents which must inform intervention strategy formulation and management.

2 GAPS AND PROBLEMS WITH SOUTH AFRICA’S ROAD SAFETY DATA
Table 1 shows a summarised assessment of the RTMC website data by classifying the data into four classes i.e., major crashes, fatalities, vehicle and licence information. This assessment provides more information on the data available on the RTMC website, the period the data cover and on the format of the available data.
The assessment of the available traffic accident data in South Africa concludes that:

- Traffic reports are not released on time on the RTMC website;
- The available data are not reported in a research-friendly format (consider Table 1). Most of the available data must be retrieved indirectly from various PDF-formatted reports on the website. The restricted data on the RTMC website that is available in EXCEL format are not provided on an on-going basis for analysis. The data must be available in summarised time series format for the most recent time frames of 10 years.
- The data on the RTMC website only report on national and provincial level even though one of the objectives of the RTMC is to establish a partnership between national, provincial and local spheres of government.
- Due to the fact that death certificates do not report the cause of death correctly (e.g., a road accident), it follows that Stats SA annual report on mortality and causes of death under estimate such reported figures.

The assessment of the available traffic accident data in South Africa concludes that:
Research undertaken by Chokotho et al. [4] report extensive data quality problems in the police data, including significant underreporting of traffic injury deaths. In addition, recording of the ‘time variables’ in the mortuary dataset was substandard. It was further concluded that not all assumptions underlying the use of the capture-recapture method were met; hence, estimates provided by this capture-recapture analysis should be interpreted with caution.

Annual reports of most municipalities do not include any data on major crashes, fatalities or vehicle and licence information in the municipality area.

3 AN ANALYSIS OF THE TRAFFIC DATA IN SOUTH AFRICA

3.1 Traffic accident trends

Figure 1 represents a very high linear relationship (correlation coefficient of 0.975) as would be expected between the number of fatal crashes and the fatalities (per 100 million vehicle kilometres travelled). From Fig. 2 follows a recently minimum ratio of 22 for the number of fatalities per 100,000 human population which were measured in 1998 and 2013. Moreover, global maximum ratios of 38 were measured in 1971 and 1972 with local maximum ratios of 36 in 1982, 37 in 1990 and 32 in 2006. Figure 2 clearly indicate that 1974 was a watershed year since prior to 1974 the number of fatalities per 10,000 motorised vehicles was higher than the number of fatalities per 100,000 human population but after 1974 the inverse is true due to motorisation, affordability of vehicles and population growth.

3.2 Statistical analysis of the traffic accident data

The traffic data is time-dependant, therefore an Auto Regressive Integrated Moving Average (ARIMA) model is used to capture the dynamics of the fatalities per human population. For more information on ARIMA models consider Gujurati & Porter [5]. ARIMA models

![Figure 1: The relationship between the fatalities and fatal crashes (Source: Own construction using data from the RTMC website).](image-url)
attempt to capture empirically relevant features (patterns) of the observed data using only information contained in the variable past values and error terms. The Box-Jenkins approach is used to select the appropriate parsimonious ARIMA model. The ARIMA model that estimates the fatality data the best is the ARIMA(1,1,0) model.

The Hodrick-Prescott (HP) filter is a univariate two-sided linear filtering technique which decomposes a time series into a long-term trend and cyclical part. This technique was first used by Hodrick and Prescott to analyse post-war U.S. business cycles in Ref. [6]. In Fig. 3,
the blue line represents the total number of fatalities, the red line shows the long-term trend and the green line indicates the cyclical part included in the fatality data.

In the Single Exponential Smoothing method $\hat{y}_{t+1} = \alpha y_t + (1 - \alpha)\hat{y}_t$, the smoothing series $\hat{y}_t$ of the actual series $y_t$ is determined as a weighted average of the past values of $y_t$ and the smoothing parameter $\alpha$ is calculated by minimizing the sum of squared errors. The Exponential Smoothing (Holt-Winters – No seasonal) method is a double smoothing method; consider Hyndman et al. [7] for more on Exponential Smoothing methods.

Other methods like the Past Values Average and Moving Averages were also used in Table 2 to capture the dynamics of the traffic data.

4 PREDICTION OF TRAFFIC ACCIDENTS

In this section, the best forecasting model will be determined by dividing the data up into a training set and a validation set. The training set is used to determine the different parameters (values) of each model in Section 3.2, and the validation set is used to determine the forecast ability of each of these models. Therefore, the values for the forecast accuracy measures given in Table 3 is the result of using the input data (number of fatalities for the period 1992–2015) with training period 1992–2012 and forecast evaluation period 2013–2015. Here, the best forecast model is illustrated to be the Average of all the Past Values which minimum values for the forecast errors e.g., root mean squared error (RMSE), mean squared error (MSE) and the mean absolute percentage error (MAPE). The Average Past Values predict 13,455 road fatalities for 2016 in South Africa.

Further, using the training period (1992–2013) and forecast period (2014–2015) on the road mortality data, the forecast results follows in Table 4. By considering these forecast

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</table>

Source: Own construction using fatality data from the RTMC website.
errors, we can conclude the best model to predict the mortality rate is the Hodrick–Prescott filter, which predict a road mortality rate of 24 for 2016.

William et al. [8] report that a Monte Carlo Simulation is a probability simulation used by decision makers for risk management thus to plan ahead for the future by estimating the relative likelihood and range of the possible uncertain (random) variable values. Hereby the decision makers can assess the likelihood of a desirable outcomes and the risk of undesirable outcomes.

Figure 4 is constructed using South Africa’s fatalities per 100,000 human population ratio for the period 2002 to 2015. From using these historical data combined with a Monte Carlo simulation, it follows that the likelihood of having a fatalities per 100,000 human population ratio in the interval (25; 27] is the highest at 28% and the profitability of having this ratio higher than 25 is equal to 71%. Hence, the Monte Carlo method implies that the probability is very high in 2016 for the realisation of a mortality rate greater than 24.

![Figure 4: The likelihood of the fatalities per 100,000 human population ratio ordered by different classes (Source: Own construction using the RTMC fatality data).](image)
5 HOW TO ACHIEVE AND SET TARGETS

Tolon-Becerra et al. [9] propose a way of meeting the required European Union road safety target on the reduction of fatalities in a certain period of time. This is done by distributing the effort between the different European Union member countries, using an inverse logarithmic function that penalise in a smooth way countries according to their base year mortality rate. Hence, countries with high base year fatality rates are assigned high rates of reduction in comparison with countries with low base year fatality rates.

This methodology if applied to the provinces in South Africa as illustrated in Fig. 5, using 2011 as base year to meet the UN’s target in [10] of halving the 2011 number of fatalities by 2020. Note that the RTMC supports the UN’s target in their annual reports.

Due to the fact that the current tendencies and results are due to yesterday’s habits, it follows that targets will only be achieved if it is possible to reduce the target by refining and defining the responsibility of the target. Therefore, the best way to meet a target is by diversifying the responsibility to different applicable responsibility levels and by refining the responsibility as much as possible. Hence, the above target methodology combined with progress monitoring must be implemented not only on provincial level but also on local municipality level and must be adapted and monitored on an annual basis. Due to the lack of municipality level road accidents data (and the impossible process of getting hold of it), it is only applied to provincial level in this paper.

6 ROAD ACCIDENT CAUSES TO BE CONSIDERED IN ROAD SAFETY STRATEGIES

6.1 Developed countries

Hughes et al. [11] provide the following traffic accidents contributing components and factors that must be managed and coordinated by a Safety Management System:

1. Human (driver/pedestrian/passenger)
   - Compliance to traffic rules (overtaking, speeding, etc.)
   - Impairment (drugs, alcohol, etc.)
   - Abilities and capabilities (license, vision, etc.)

![Figure 5: Setting fatality and mortality targets for each province (Source: Own construction using Stats SA population data and RTMC fatality data).](image-url)
• Attitude and attention (emotion, phone distraction, etc.)
• Helmets and protection clothing utilisation
• Seatbelt utilisation.

2. Vehicle(s)
• Maintenance, inspections, damage
• Condition of wheels and tires
• Condition of brakes
• Condition of steering, pedals, levers, lights and suspension
• Design standards
• Overloading.

3. Road infrastructure
• Surface (friction, shoulders, potholes, etc.)
• Geometry (gradient, lanes, no shoulder, curves, etc.)
• Poor maintenance
• Traffic volumes
• Inadequate signs, reflectors, signal, lighting, etc.
• Obstacles (intersection type, crosswalk, island, etc.)
• Poor road system (entry and exist of vehicles).

4. Transport and land use
• Transport alternatives, other modes
• Spatial arrangement, co-location
• Accessibility - remoteness, location, service levels
• Transport integration.

5. Environmental
• Weather (fog, rain, etc.)
• Smoke
• Wildlife
• Dawn, dusk, night and sun.

6. Socio-economic circumstance
• Economics (finance, funding)
• Employment structure
• Population growth
• Politics and government
• Social norms and background
• Travel purposes and activities
• Legal (regulation, liability, insurance).

7. Crash response system
• Emergency services and rehabilitation.

6.2 Developing countries

According to the work done by the World Health Organisation (cf. [12–15]), Nantulya and Reich [16] and Juillard et al. [17] the main reasons for the high road traffic fatality and injury rates in Africa are due to one or more of the following considerations:

• Road infrastructure [with the main emphasis on the lack of pedestrian subways and sidewalks (pedestrians) cycling infrastructure lanes and the uncorrelated growth between road infrastructure improvement and the number of commuters];
• Human: disregard of cyclists and pedestrians by drivers (inclusive of non-motorised traffic);
• Road infrastructure: lack of road signs;
• Transport and land use: the traffic modal mix on the roads;
• Safety management system: ineffective planning by government inclusive of health,
  emergency and transport agencies due to poor sampling techniques, varying traffic fatal-
  ity definitions used by different reporting agencies, underreporting, reporting errors and
  lack of integration between reporting agencies;
• Socio-economic circumstance and transport and land use: non-existing unavailability or
  non-affordable public transport;
• Socio-economic circumstance: increase in the utilisation of motorised transport due to
  economic development, affordability and availability.

Traffic Offence Survey [18] reports the five highest contributory factors in 2015 to fatal
 crashes in South Africa are due to:

• Human: Jay-walking pedestrians (41.6%);
• Human: Speed too high for circumstances (9.2%);
• Human: Hit and run (8.8%);
• Vehicle: Tyre burst prior to accident (4.7%);
• Human: Intoxicated driver with liquor/drug usage (4.3%).

These five factors contribute 69% to all fatal accidents in South Africa.

From the above, it follows that main components on which developing countries must
 focus on in their road safety strategies is the human, vehicle, road infrastructure, socio-
 economic, safety management system and transport and land use.

7 STRATEGIES TO REDUCE TRAFFIC ACCIDENTS

Studying the reduction of road mortalities in the Netherlands (1972), UK (1983) and Spain
 World Health Organisation (cf. [12–15]), Nantulya and Reich [16], Juillard et al. [17] and
 Traffic Offence Survey [18] it follows that road safety can be improved if the strategies,
 function, objectives and output strive on a continuous basis to improve:

Safe Management:

• Risk management: (identification, assessment, analysis, prediction)
• Information (data and research): Use common (police, hospital, mortuary, Department
  of Transport, Stats SA) accident database. Allowing for more detailed and reliable analy-
  ses of data. On municipality level, the location of crash incidents must be used to deter-
  mine hotspots and to create a hotspot map of crashes in the municipal areas and thereby
  identifying priority spatial locations for strategy formulation
• Standards and well-defined targets. (Consider Section 5 on ways to achieve targets). Each
  municipality needs to prioritise and apply sound traffic safety measures in line with the
  applicable legislative framework with given targets that are based on their appropriate base
  year performance in order to ensure and boost the countries but also the municipality’s
  road safety and economic statistics
• Capability (skills, knowledge, experience)
• Capacity (financial, human, system, technology)
• Systems (processes, structures, procedures, standards)
• Integration (vertical coordination on national, provincial and local spheres and horizontal alignment of sources on road accident data all using the same database and definitions)
• Implementation and improvement of policy, planning, design, installation, maintenance, monitoring, evaluation, revision.

Safer road infrastructure:
• Improved design of roads and related supporting infrastructures
• Identify pedestrian hazardous locations
• Identification of hazard location (traffic accident hotspots)
• Information on the reason for accident.

Safer vehicles:
• Strong political commitment on design standards
• Enforcement of legislation
• Inspections.

Human component behaviour change:
• Education: Educate young people or road safety using a guide like the Road Safety Cities in Europe, Handbook [21]
• Information (campaigns) on crashes to better the understanding of the risk
• Strong enforcement initiatives with the focus on
  • speed control
  • alcohol consumption (‘drink and drive initiatives’)
  • promotion of helmet utilisation
  • promotion of seatbelt utilisation
  • road user sensitivities related to both motorised and non-motorised modes of transport.

Transport and land use
• Sustainable transport systems like bus rapid transit, to decrease traffic accidents and traffic congestion.

ACKNOWLEDGEMENTS
The author gratefully acknowledges the National Research Foundation (GUN No. 81221) for financial support.

REFERENCES


