



# EPIDEMIOLOGY AND RISK OF ROAD TRAFFIC MORTALITY IN SOUTH AFRICA

ANESH SUKHAI, ANDY P JONES AND ROBIN HAYNES

## ABSTRACT

In view of the large and increasing road traffic fatality burden in South Africa, this study describes the distribution of the risk of fatal road traffic injuries according to population and rural-urban characteristics in the country, between 2002 and 2006. Two different exposure-based rates relating to population counts and vehicle ownership were calculated to quantify and explicate traffic fatality risk. Demographic, road user and temporal characteristics were examined, as were a number of measures relating to the geography of road traffic fatality risk, which has not been previously examined for South Africa. Geographical analysis was undertaken at the District Council Municipality (DC) census level where four area-based measures of rurality were computed: percentage rural population, average population size (of Main Place census areas within each DC), crude population density and person-weighted population density. There were substantial variations in risk associated with population, temporal and seasonal characteristics, and measures of rurality. Some large rural-urban disparities that differed by road user categories and also by the measures used to quantify risk and to define rurality, were apparent between the DCs. The findings provide new insights on the distribution of road traffic fatalities in South Africa that should guide intervention strategies targeted at addressing this considerable public health challenge.

**Key Words:** Epidemiology, traffic mortality, districts, South Africa

## Introduction

Understanding the distribution of the risks of road traffic deaths is fundamental to improving road safety, especially in many low- and middle-income countries (LMICs) that exhibit a disproportionately higher burden, but have a relative lack of analytical research on their determinants, in comparison with high-income countries. Of the global burden of road traffic injuries, LMICs experience 85% of all fatalities and account for 90% of all Disability Adjusted Life Years lost (Krug et al., 2000). Globally, road traffic injury was ranked as the 11<sup>th</sup> leading cause of death in 2002 (Mathers et al., 2002), but the South African National Burden of Disease Study in 2000 showed these injuries to be the 7<sup>th</sup> leading single cause of death in the country, accounting for 12% of deaths from all causes (Bradshaw et al., 2003). The national incidence of crashes and fatalities in South Africa has also shown increasing trends. For example, the Road Traffic Management Corporation (RTMC) showed that there were approximately 12 500 fatal crashes and 15 400 fatalities in 2006, increases from 2001 by 42% and 37%, respectively (NDoT, 2007).

Exposure is a significant component of traffic-related risk (Peden et al., 2004) and usually relates to the volume of accident opportunities that a road user encounters in the traffic system (Chapman, 1973; Risk and Shaoul, 1982). Several exposure-based indicators are commonly used to compare traffic-related risk between populations and areas. Despite the inherent limitations to many of these measures, the population-based fatality rate is the preferred indicator to show the public health impact of crashes in relation to other disease conditions (Bangdiwala et al., 1985; Garg and Hyder, 2006; Christie et al., 2007).

South Africa's population-based fatality rate is particularly high when compared with other low- and middle-income countries (LMICs), especially in the African continent. In an extensive review of 73 studies on road traffic injuries in LMICs, Odero et al. (1997) considered 31 studies that

included data on population and vehicle-based rates. Of the 13 studies reviewed in Africa, South Africa had the highest reported population-based fatality rate of 35.8 deaths per 100 000 population followed by Swaziland with 28.0 deaths per 100 000 population. The lowest rate was reported for Tanzania with 4.0 deaths per 100 000 population. Generally, high population-based fatality rates were shown to be characteristic of countries having relatively higher income economies compared to other LMICs. However, South Africa was reported to have the lowest vehicle-based fatality rate of 20.5 deaths per 10 000 vehicles among these 31 studies. Based on data from the RTMC (NDoT, 2007), the level of vehicle ownership in South Africa was 161 per 1000 people in 2006, a high value for the continent. The growing number of motor vehicles in LMICs is often blamed for their high burden of road traffic fatalities (Nantulya and Reich, 2002; Peden et al., 2004).

Geographical analyses provide a useful methodology for highlighting regional differences in the distribution of the risk of road traffic fatalities, and as suggested by Whitelegg (1987), a geographical approach may also allow for an improved understanding of the nature, causes and progression of these injuries. Systematic analyses of geographical distributions and variations in road traffic fatalities have not been undertaken in the South African context. Considering the escalating burden of road traffic deaths in South Africa, analyses of the geography of risk may provide new insights to guide intervention strategies targeted at reducing this public health challenge.

Characteristics such as those relating to rurality (or urbanisation) provide useful area-based dimensions for understanding the geography of road traffic deaths. Generally, unintentional injury death rates have been shown to be higher in rural than in urban areas (Peek-Asa et al., 2004; Boland et al., 2005). In terms of road traffic injuries, higher death rates have also been reported for rural areas in Africa (Afukaar et al.,

2003), Europe (Bentham, 1986; Boland et al., 2005) and the United States (Brown et al., 2000; Clark and Cushing, 2004; Peek-Asa et al., 2004; Zwerling et al., 2005; Paulozzi, 2006). In these studies, rurality is often defined using population density (Baker et al., 1987; Muelleman and Mueller, 1996; Clark and Cushing, 2004; Peek-Asa et al., 2004; Paulozzi, 2006). In terms of road users, studies in high-income countries have generally shown higher fatal injuries in rural areas for vehicle occupants (Baker et al., 1987; Chen et al., 1995; Muelleman and Mueller, 1996). However, pedestrian risk and injury are generally higher in urban areas. For example, Petch and Henson (2000) reported the risk of a pedestrian accident for children living in urban areas to be around five times higher than that for those living in rural areas. At present, it is not clear whether such rural-urban patterns in road traffic deaths manifest in low- and middle-income countries like South Africa.

Higher fatality rates in rural areas are often attributed to higher travel exposure, and poorer injury outcomes due to faster speeds and lower quality of medical care. However, the relationship between rurality and road traffic fatalities is complex with some studies showing higher rural fatality rates to persist after controlling for these factors. For example, in the United States, Clark and Cushing (2004) showed population density to be a moderately strong predictor of rural but not urban traffic mortality rates, after controlling for vehicle miles travelled. In terms of injury severity, Muelleman et al. (2007) showed the risk of fatal road traffic injuries to be nearly twice

deaths from all causes (Bradshaw et al., 2003). In terms of road traffic fatalities, Meel (2007) showed a relatively high fatality rate of 63 per 100 000 population for Transkei, a largely rural region in the Eastern Cape of South Africa.

This paper addresses the paucity of South African data on epidemiological distributions in the risk of fatal road traffic injuries. Demographic, road user and temporal characteristics are examined, and there is a particular focus on geographical variations in road traffic fatality risk. The efficacy of various measures of rurality for explaining the geographical variations in road fatality risks are examined and the implications of the results for strategies to prevent or reduce the burden of road traffic deaths in South Africa are discussed.

### Data and methods

The study was based on a cross-sectional geographical design at the District Council Municipality (DC) census level. It focussed on all fatal traffic injuries occurring in South Africa from 2002 to 2006. Based on the new municipal structure implemented by the Municipal Demarcation Board in mid-2000 (StatsSA, 2004b), there are 53 DCs, including 6 Metropolitan areas and 47 District Councils that cover the remaining non-metropolitan areas. The DC level was the lowest level at which all data could be disaggregated for the analysis in this study. Furthermore, analysis at this scale, where significant resource, policy and intervention planning occurs, allows for a macro-level assessment to be undertaken of spatial variation among observed fatalities. The five-year study period included the earliest and most recent years for which comprehensive individual-level traffic fatality data was available.

Table 1: Summary of outcome and rurality measures for District Council Municipalities, 2002-2006

Variable	Source data	Min	DC Min	Max	DC Max	Mean
<b>Outcome measures</b>						
Total fatalities	NDoT	207	Namakwa	3 811	Johannesburg	947.3
Average annual fatalities per 100 000 population	NDoT, StatsSA	9.0	Alfred Nzo	114.1	Central Karoo	27.6
Average annual fatalities per 10 000 vehicles	NDoT, NHTS	7.3	Cape Town	105.0	Central Karoo	30.7
<b>Denominators for outcome measures</b>						
Total population	StatsSA	60 483	Central Karoo	3 225 812	Johannesburg	845 656.1
Total vehicle population	NHTS	6 571.9	Central Karoo	651 486.0	Cape Town	101 403.5
<b>Rurality variables</b>						
% Rural population	StatsSA	0.3	Johannesburg	99.0	Bohlabela	48.6
Population size	StatsSA	492.9	Chris Hani	1 055.7	Zululand	816.6
Crude population density	StatsSA	0.9	Namakwa	1 962.1	Johannesburg	180.4
Person-weighted population density	StatsSA	248.0	Umkhanyakude	15 319.9	Johannesburg	3 795.7

Key to data sources: NDoT- National Department of Transport (National Traffic Information System); StatsSA- Statistics South Africa (Community Profiles Databases with 2001 population census and GIS data); NHTS- South African National Household Travel Survey (2003 database, supplied by TRC Africa).

as high in rural areas of Nebraska (defined by population size and adjacency to a metropolitan area) even after controlling for injury severity.

While rural-urban variations in road traffic injuries have not been studied in South Africa, previous small area studies in rural settings suggest that disparities may be present. Kahn et al. (1999) showed a high prevalence of fatal injuries from all causes in Agincourt, a relatively small and rural sub-district with a population of about 63 000 people. Approximately one-third of all deaths among children aged 5-14 years and in the economically active group from 15-49 years were injury-related, whilst nationally, injuries account for only 12% of

### Outcome data and indicators

Table 1 provides a summary of the outcome measures, denominators, and measures of rurality examined. The data on road traffic deaths, supplied by the National Department of Transport (NDoT), is based on the routine completion of an 'accident report' form by police personnel for all traffic-related injuries. Fatalities occurring up to six days after a collision are deemed traffic-related and included within a fatality database. There are some limitations with this definition as it is shorter than the 30 day cut-off recommended by the World Health Organisation for classifying victims of road traffic collisions (Peden et al., 2004). While less of a problem with fatal than non-fatal data, under-reporting of deaths in the police records used in our study is likely to have occurred. While the problem

may be global (Peden et al., 2004), it is of particular concern in low- and middle-income countries lacking resources (Odero et al., 1997). A French study (Aptel et al., 1999) that compared police, hospital and vital statistics showed that up to 15% of crash fatalities are not captured by police records. The study also showed higher levels of under-reporting in rural than urban areas. In South Africa, the extent and nature of under-reporting is unknown but is likely to be higher.

As the location of individual collisions is not recorded, the police station assigned to a traffic fatality provided the most reliable geographical reference for the events. Hence boundary data for police stations was obtained from the 1997 Human Sciences Research Council Police Station Boundaries dataset. Boundary data for the DCs, based on the new municipal structure, was also extracted from the Statistics South Africa (StatsSA) Community Profiles Databases. Using the ArcGIS 9.2 Geographical Information System (GIS), the centroid (centre point) of each police station service boundary was determined and this location was used to allocate each road traffic fatality to its respective DC.

Data on demography, road user characteristics, and temporal and seasonal factors were extracted from the Department of Transport fatality database. Two risk exposure measures, population counts and vehicle ownership, were included for the DCs. Travel-related exposure measures such as driving distance or driving time were not included since disaggregated data was not available at the DC level.

Population data for the DCs was based on the 2001 census population counts from StatsSA. Data on the registered vehicle population or vehicle ownership was not obtainable at the DC level; hence 'vehicle access' was used as a proxy measure. Data on household access to the number of vehicles in running order for private use within each DC was extracted from the South African National Household Travel Survey 2003 database. The measure included vehicles owned by households, vehicles owned by relatives/friends and vehicles owned by employers.

The fatality data and the risk exposure measures were used to produce two types of commonly used outcome indicators; the population and vehicle-based fatality rates. In calculating the indicators, the outcome data was averaged over the five-year study period and annualised rates were calculated. For the population-based fatality rate, the number of deaths (for population cohorts and DCs) was divided by the respective population exposed, and expressed as the number of deaths per 100 000 population. The overall age-adjusted directly standardised fatality rate was also calculated and compared with the overall crude rate for the DCs. The two rates showed to be very similar and were highly correlated ( $r=0.993$ ,  $p<0.001$ ). Consequently, for consistency especially with the rurality quartile analyses where standardised rates were not appropriate, crude fatality rates were used throughout the study. In terms of the vehicle-based rates, the number of fatalities was divided by the total 'vehicle access' for each DC, and expressed as the number of deaths per 10 000 vehicles. Of note was that the national road traffic fatality rate of 18.7 per 10 000 vehicles calculated using data within this study, was similar to the rate of 16.8 per 10 000 registered vehicles reported by the RTMC for 2005 (NDoT, 2007).

#### *Rurality data*

Four variables relating to rurality were selected against which between-DC variations in mortality were examined. The rurality variables relate to physical area-based dimensions of rurality. Measures relating to social influences of deprivation were not included since Index of Multiple Deprivation data was not available for the DCs, and it is well recognised that deprivation indices generally measure urban disadvantage much better than rural (Niggebrugge et al., 2005).

The first variable calculated was the percentage of the population living in rural areas. Enumerator Areas are the lowest geographical level used for non-population based census dissemination and are defined as rural or urban based on the predominant land use and type of settlement within the EA by StatsSA (StatsSA, 2003). For each DC, urban and rural populations for the Enumerator Areas were summed and the percentage of the population living in rural areas was calculated.

The second measure was the average population size, calculated by averaging the populations of all census-defined Main Places within each DC. The Main Place level may be regarded as a comparable level to that used internationally for calculating population sizes and defining rurality (StatsSA, 2003). Main Places represent the third lowest census level (after EAs and Sub-places) and include cities, towns, tribal areas and administrative areas (StatsSA, 2004). Analysis using the StatsSA community profiles databases showed large variability in the population sizes of the 3 109 Main Places, with mean and median values of about 14 800 and 4 200 respectively.

The remaining two measures were crude population density and person-weighted population density. The crude measure was calculated for each DC by dividing the total population by the land area in square kilometres. To account for population clustering, the person-weighted population density was calculated for each DC as the population-weighted sum of crude population densities for all 'Small Areas' within the DC. The Small Area Layer, created by combining all EAs with a population smaller than 500 with adjacent EAs within a Sub-place, is the lowest geographical level for which population data is available (StatsSA, 2005).

The four rurality variables were generally well correlated with most correlation coefficients in excess of 0.7 and significant at the 1% level. Exceptions were the correlations between the percentage rural population and population density ( $r=-0.43$ ,  $p=0.001$ ) as well as between the percentage rural population and population size ( $r=-0.41$ ,  $p=0.003$ ).

#### *Statistical analysis*

The SPSS version 14.0 (SPSS Inc) software was used to explore associations between the outcome indicators and explanatory variables. For all statistical analyses, the level of significance was set at  $\alpha=0.05$ . Confidence intervals around rates were calculated based on the formula  $[\text{Rate} \pm (1.96 * \text{Rate} / \sqrt{N})]$ , where N represented the number of cases over the 5-year study period.

## Results

### Demography & road user characteristics

The 53 DCs, aggregated from 1 030 police station areas, contained 50 205 recorded traffic fatalities over the five-year period 2002-2006. The pedestrian user group accounted for the highest proportion of traffic-related deaths (42.4%). Among pedestrians, and where demography was known, males accounted for 76.4%, blacks and coloureds combined 96.9%, and the 25-59 year age group 57.5% of cases.

Table 2 shows that pedestrian fatalities, at a rate of 9.5 per 100 000 population, were the largest proportional contributor to the national annual fatality rate of 22.4 deaths per 100 000 population. The fatality rate for passengers was higher than that for drivers (6.5 and 5.1 deaths per 100 000 population, respectively). In terms of ethnicity, Table 2 shows that there were very strong disparities between groups based on road user type. The highest traffic fatality rate per 100 000 population was among whites (28.7), due mainly to this group having the highest driver fatality rate of 15.7. The highest rates per 100 000 population for passengers was among Asians followed by coloureds (9.4 and 8.3, respectively) and for pedestrians was among coloureds followed by blacks (11.9 and 10.1, respectively).

Table 2: Average annual fatality rates per 100 000 population, 2002-2006, for road user by ethnicity

	Vehicle Driver			Vehicle Passenger			Pedestrian			Bicycle or Motorcycle Rider			Total		
	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI
Asian/Indian	558	10.0	9.2-10.8	525	9.4	8.6-10.2	220	3.9	3.4-4.5	23	0.41	0.24-0.58	1 326	23.8	22.5-25.1
Black African	6 326	3.6	3.5-3.7	11 366	6.4	6.3-6.5	17 956	10.1	10.0-10.3	987	0.56	0.52-0.59	36 635	20.7	20.5-20.9
Coloured	1 057	5.3	5.0-5.6	1 649	8.3	7.9-8.7	2 367	11.9	11.4-12.3	221	1.1	1.0-1.3	5 294	26.5	25.8-27.2
White	3 369	15.7	15.2-16.2	1 641	7.6	7.3-8.0	439	2.0	1.9-2.2	720	3.4	3.1-3.6	6 169	28.7	28.0-29.5
Total <sup>a</sup>	11 438	5.1	5.0-5.2	15 495	6.9	6.8-7.0	21 286	9.5	9.4-9.6	1 984	0.9	0.8-0.9	50 205	22.4	22.2-22.6

<sup>a</sup>Totals for road users include cases with unknown ethnicity

The mortality rate amongst males of 34.9 was 3.5 times higher than the female rate of 10.1 per 100 000 population. Table 3 shows that the highest rates per 100 000 population (25.5) was among young adults (25-34 years) followed by 22.9 for older adults (35-59 years) with this pattern being consistent for both males and females. Only drivers (both male and female) and female pedestrians had higher rates among older compared to younger adults. The largest difference between male and female rates was among drivers, with values being 13 and 12 times higher for males in the 25-34 and 35-59 year age groups, respectively.

Table 3: Average annual fatality rates per 100 000 population, 2002-2006, for road user by age-sex group

	Vehicle Driver			Vehicle Passenger			Pedestrian			Bicycle or Motorcycle Rider			Total			
	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI	N	Rate	95% CI	
Female	1-14	0	0	-	523	1.6	1.4-1.7	1 288	3.8	3.6-4.0	6	0.02	0.00-0.03	1 817	5.4	5.1-5.6
	15-24	99	0.42	0.34-0.50	800	3.4	3.2-3.6	541	2.3	2.1-2.5	21	0.09	0.05-0.13	1 461	6.2	5.9-6.5
	25-34	177	0.94	0.80-1.07	1 063	5.6	5.3-6.0	633	3.3	3.1-3.6	16	0.08	0.04-0.13	1 889	10.0	9.5-10.4
	35-59	298	1.1	0.93-1.17	1 374	4.9	4.6-5.1	1 049	3.7	3.5-3.9	21	0.07	0.04-0.11	2 742	9.7	9.3-10.1
	60+	67	0.66	0.50-0.82	323	3.2	2.8-3.5	312	3.1	2.7-3.4	1	0.01	0.00-0.03	703	6.9	6.4-7.5
Male	1-14	6	0.02	0.00-0.03	718	2.1	2.0-2.3	1 961	5.8	5.6-6.1	95	0.28	0.23-0.34	2 780	8.3	8.0-8.6
	15-24	806	3.5	3.3-3.8	1 324	5.8	5.5-6.1	1 567	6.9	6.5-7.2	285	1.3	1.1-1.4	3 982	17.5	17.0-18.0
	25-34	2 115	12.1	11.6-12.6	1 831	10.5	10.0-11.0	3 052	17.5	16.9-18.1	349	2.0	1.8-2.2	7 347	42.1	41.1-43.0
	35-59	3 249	13.1	12.6-13.5	1 887	7.6	7.3-7.9	3 783	15.2	14.8-15.7	462	1.9	1.7-2.0	9 381	37.8	37.0-38.6
	60+	374	6.0	5.4-6.6	229	3.6	3.2-4.1	620	9.9	9.1-10.7	60	0.96	0.71-1.20	1 283	20.4	19.3-21.6
Total <sup>a</sup>	1-14	6	0.01	0.00-0.02	1 261	1.9	1.8-2.0	3 255	4.8	4.7-5.0	101	0.15	0.12-0.18	4 623	6.9	6.7-7.1
	15-24	906	2.0	1.8-2.1	2 135	4.6	4.4-4.8	2 109	4.5	4.4-4.7	306	0.66	0.59-0.73	5 456	11.8	11.5-12.1
	25-34	2 294	6.3	6.0-6.6	2 907	8.0	7.7-8.3	3 694	10.2	9.8-10.5	365	1.0	0.9-1.1	9 260	25.5	24.9-26.0
	35-59	3 553	6.7	6.5-6.9	3 275	6.2	6.0-6.4	4 838	9.1	8.9-9.4	484	0.91	0.83-0.99	12 150	22.9	22.5-23.3
	60+	442	2.7	2.4-2.9	552	3.4	3.1-3.6	933	5.7	5.3-6.1	61	0.37	0.28-0.47	1 988	12.1	11.6-12.7

<sup>a</sup>Totals for age groups include cases with unknown sex

### Temporal and seasonal variations

The findings of the temporal analyses, with fatalities assigned to the nearest hour of occurrence, showed that fatalities peaked over the evening hours (17h00-01h00 52.8%) with 9.5% of cases occurring around 19h00 (Figure 1). Other peaks are apparent over weekends (Saturday & Sunday 42.4%), with 24% of cases occurring on Saturdays, and in December (12.7%). An examination of the distribution of deaths by road user type in Figure 1 shows that pedestrians accounted for by far the highest numbers of fatalities for all high-risk periods mentioned above, with the peak over evening hours being most notable. Analysis of the particularly high number of pedestrian fatalities during the evening hours revealed that cases were mostly male (77.8%), black (85.6%) and in the 35-59 followed by 25-34 year age groups (37.6% and 28.7%, respectively).

### Variations associated with rurality

Figures 2-3 show the average annual fatality rates (with 95% confidence intervals) for the two outcome indicators by quartiles of the four rurality variables. Quartiles are ordered by increasing rurality for each of the rurality variables.

With the overall population-based fatality rate, and in terms of the percentage rural population and person-weighted

population density measures, Figure 2a shows that the highest fatality rates are in relatively urban areas (quartile 2). In terms of the remaining rurality variables (population size and crude population density), the highest fatality rates are apparent in the most rural areas (quartile 4). With the pedestrian group, population-based fatality rates are similar across the rural and urban quartiles but a slight decreasing trend with increasing rurality is apparent (Figure 2b). In terms of the non-pedestrian group, the pattern in fatality rates across the quartiles is similar to that found for the overall combined group (Figures 2c & 2a).

Figure 1: Road user by temporal and seasonal variations in fatalities, 2002-2006 (n=50 203)

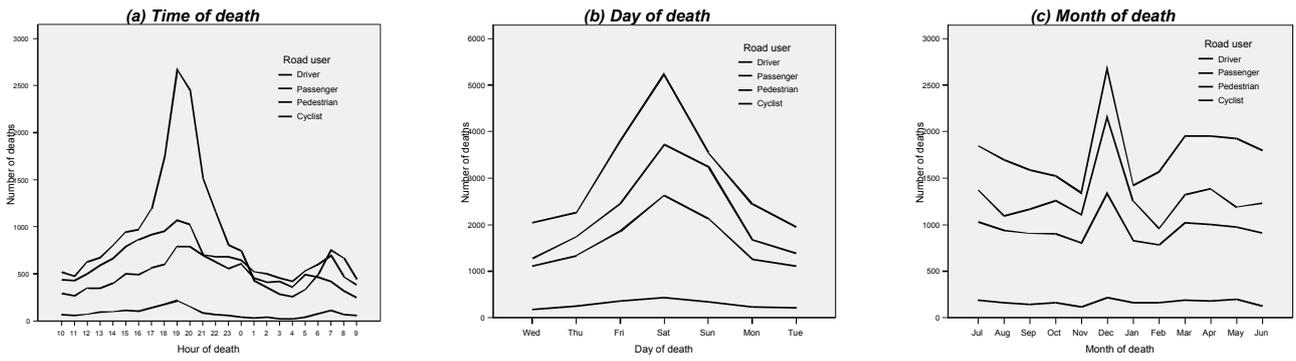
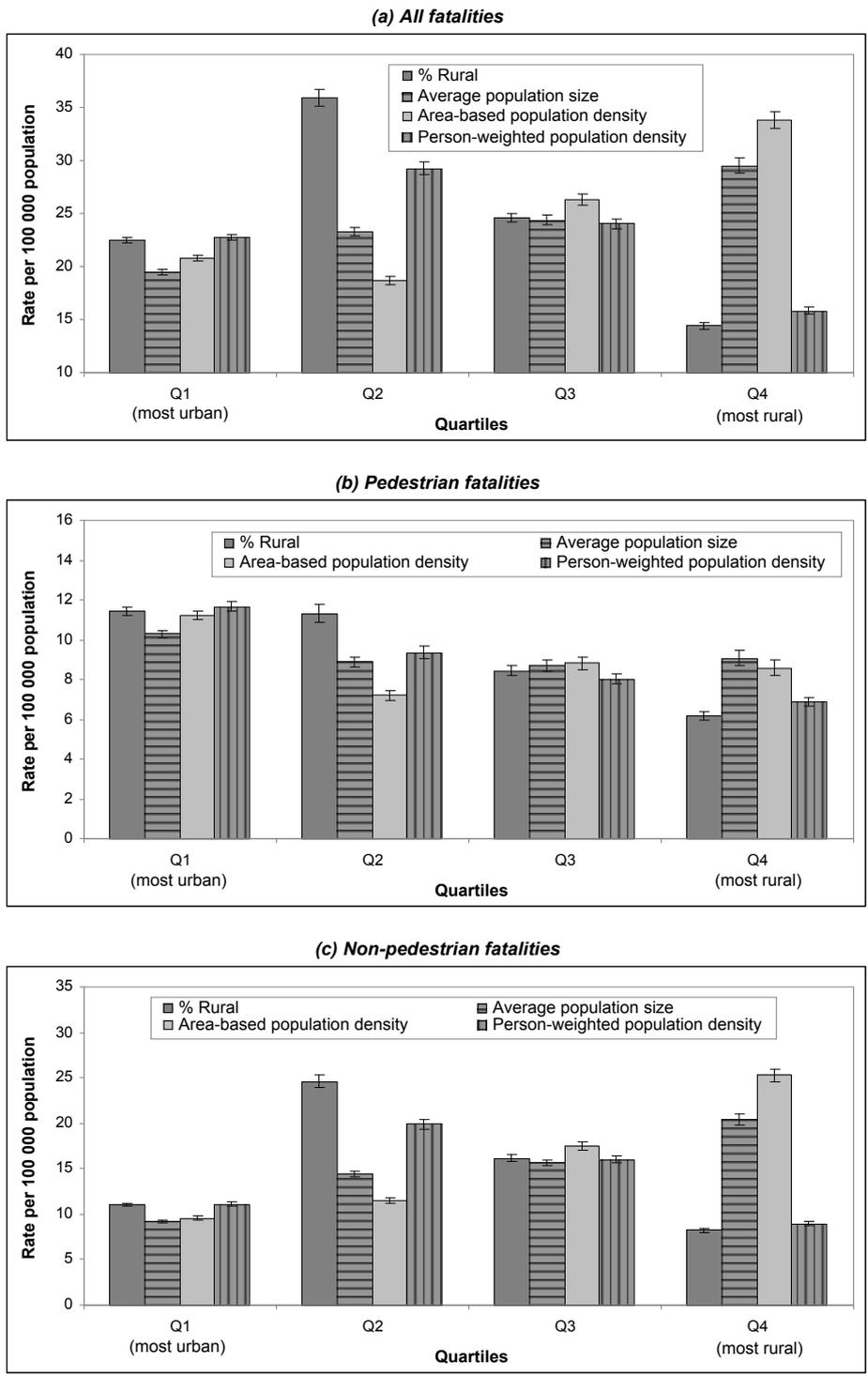


Figure 2: Average annual fatality rates per 100 000 population by quartiles of rurality variables and road user group, 2002-2006



In terms of the overall vehicle-based fatality rate (Figure 3a), the lowest rates for all rurality variables are clearly apparent in the most urban areas (quartile 1). Both the pedestrian and non-pedestrian groups show a similar pattern to the overall group in the variation of vehicle-based fatality rates across the different rurality quartiles. However, there is a greater differentiation between highly urban areas (quartile 1) and other areas for the non-pedestrian group than the pedestrian group (Figures 3c & 3a).

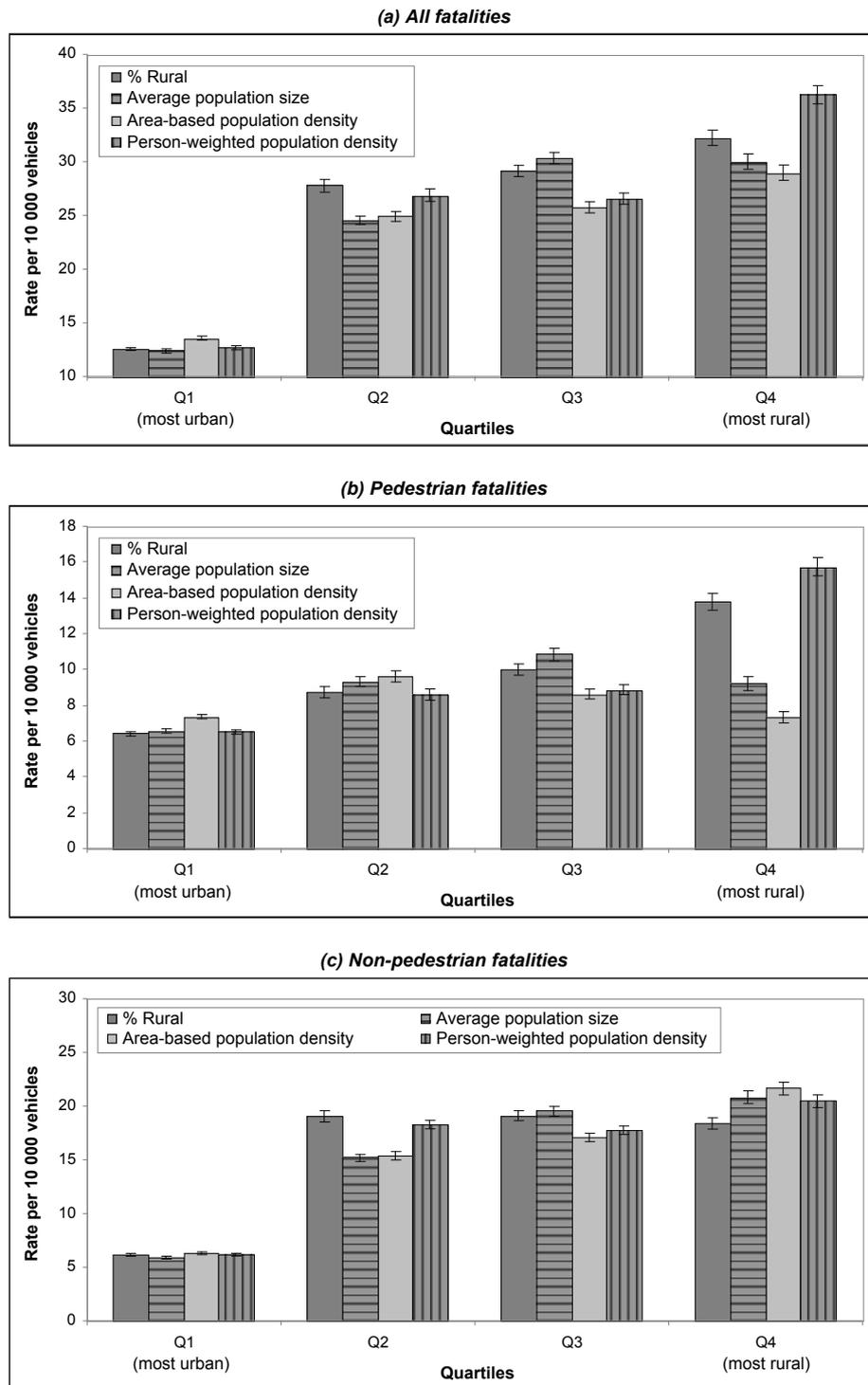
*Geographical variation*

Figures 4-7 show maps of the geographical distribution of fatalities by the outcome indicators. Figure 4 shows that the highest population-based fatality rates are concentrated in the

South West and North East of the country. The character of the DCs with the highest fatality rates conforms with the earlier finding of an elevated risk in areas with an urban character when rurality was defined by percentage rural population and person-weighted population density. This is particularly the case for the concentration of DCs in the South West of the country where five of the six DCs (including Central Karoo) are in quartile 2 of both the rurality measures (Namakwa was the exception being in quartile 3 of person-weighted population density).

The difference in distribution of the population-based fatality rates for pedestrian and non-pedestrian fatalities is shown in Figures 5 and 6. With the exception of one DC in

Figure 3: Average annual fatality rates per 10 000 vehicles by quartiles of rurality variables and road user group, 2002-2006



the South West (Boland), the remaining quintile of DCs with the highest pedestrian fatality rates are concentrated in the North/North East (North West and Gauteng Provinces) and in the Eastern province of KwaZulu-Natal (Figure 5). The non-pedestrian fatality rate shows a similar distribution to the

overall population-based fatality rate (Figure 6). Among the pedestrian group, most of the DCs with the highest fatality rate have urban characteristics on most of the rurality variables and include the two largest metropolitan areas, Johannesburg and Ethekwini (Durban).

Figure 4: Fatality rate per 100 000 population for District Council Municipalities in South Africa (2002-2006 annual average)

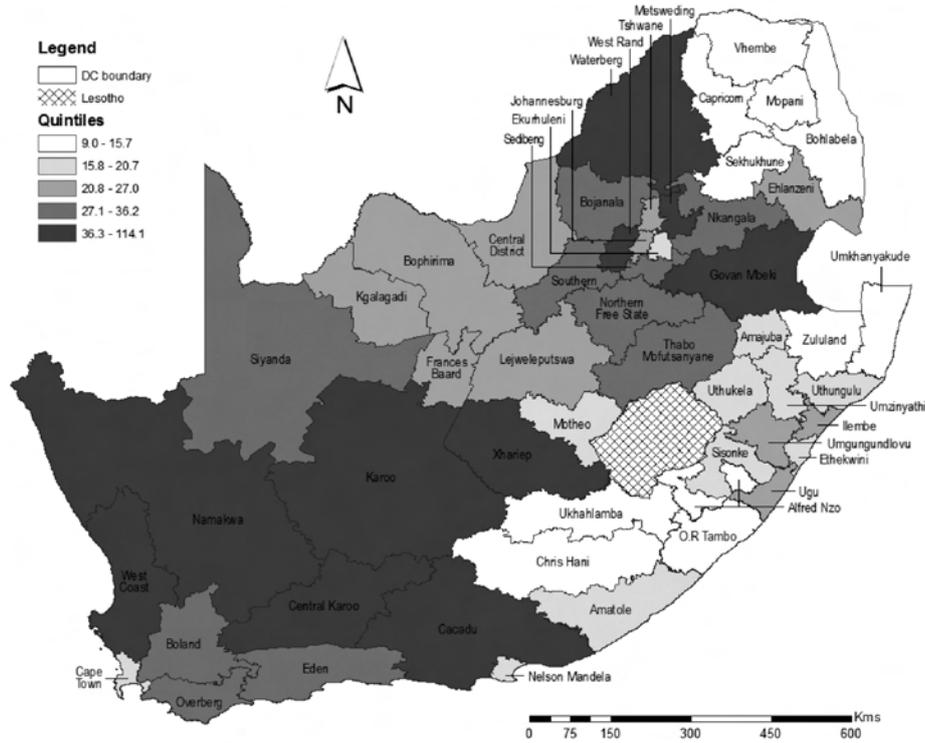


Figure 5: Pedestrian fatality rate per 100 000 population for District Council Municipalities in South Africa (2002-2006 annual average)

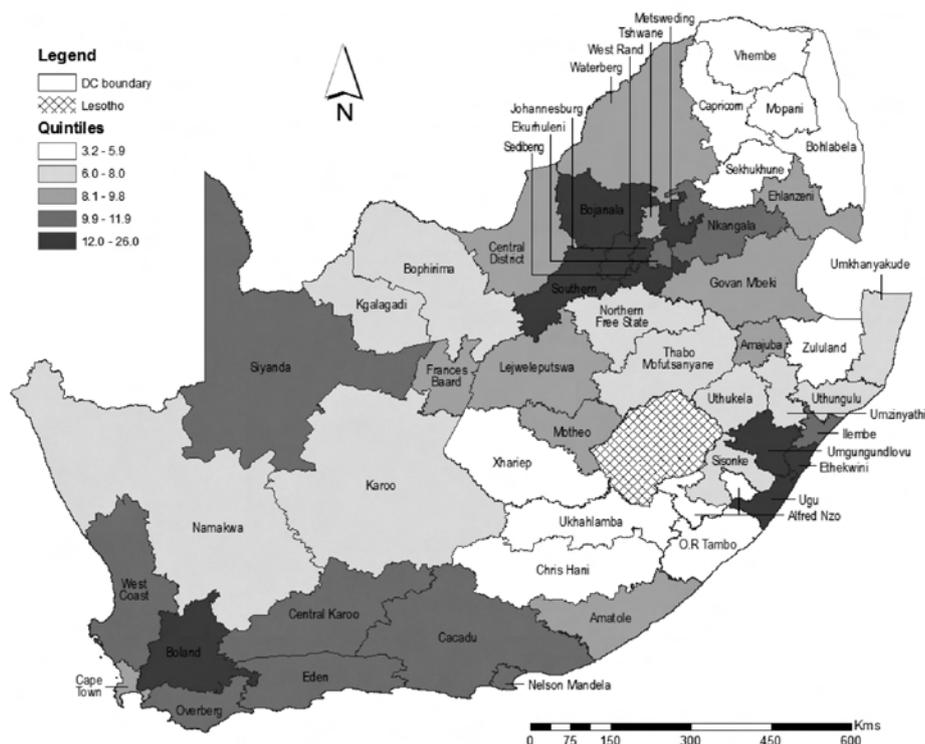
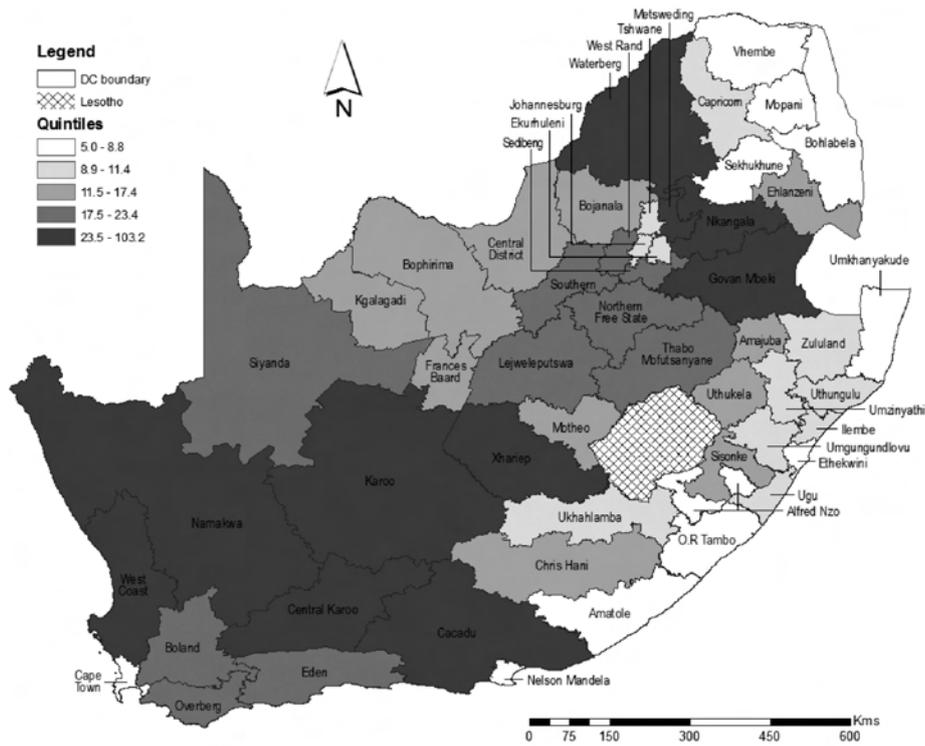


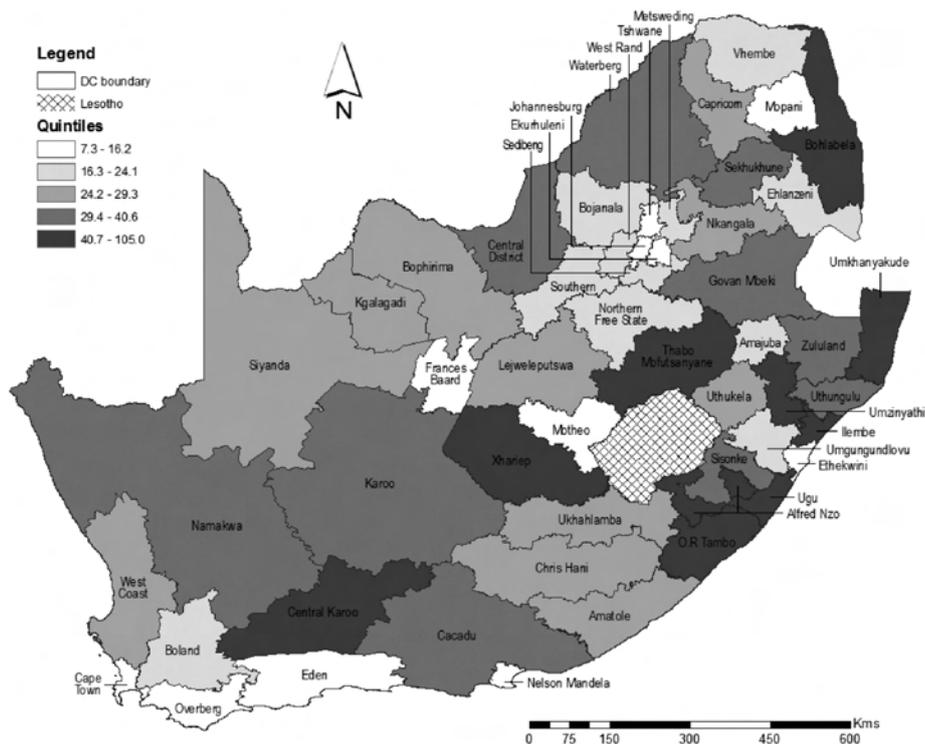
Figure 6: Non-pedestrian fatality rate per 100 000 population for District Council Municipalities in South Africa (2002-2006 annual average)



Metsweding, showing urban characteristics only on the percentage rural population measure and Ugu, only on the measure of crude population density, are exceptions. Among the non-pedestrian group, most of the DCs with the highest fatality rate also have an urban character but only on the percentage rural and person-weighted population density measures (quartile 2), also similar to that found for the overall population-based fatality rate. It is of note that only Metsweding, with the highest pedestrian fatality rate, is present among the DCs with a high fatality rate for both the pedestrian and non-pedestrian groups.

Finally, in terms of the vehicle-based fatality rate, Figure 7 shows Central Karoo to be among the quintile of DCs with the highest fatality rates, with the remaining DCs generally located in the Eastern part of the country. Most of the DCs with the highest vehicle-based fatality rates are rural, based on the percentage rural population and person-weighted population density. Central Karoo and Xhariep are exceptions, considered urban (quartile 2) on both these measures.

Figure 7: Fatality rate per 10 000 vehicles for District Council Municipalities in South Africa (2002-2006 annual average)



## Discussion

Our study shows the occurrence of road traffic fatalities in South Africa to be complex, with substantial variation in population, temporal and seasonal characteristics, and in the geographical distribution of cases. Furthermore, geographical analyses showed large rural-urban disparities between DCs that differed by the category of road user and according to the measures used to quantify risk and to define rurality.

The large burden of road traffic fatalities, especially in low- and middle-income countries, among historically disadvantaged populations, males, the economically active age groups, and the pedestrian road user group is well documented in the literature (see Odero et al., 1997; Peden et al., 2004). The relatively high driver rates among whites and males found in this study may be related to relatively higher vehicle ownership or relatively more frequent travel as vehicle drivers among these groups. However, these measures of exposure could not be assessed in this study since disaggregated data were not available.

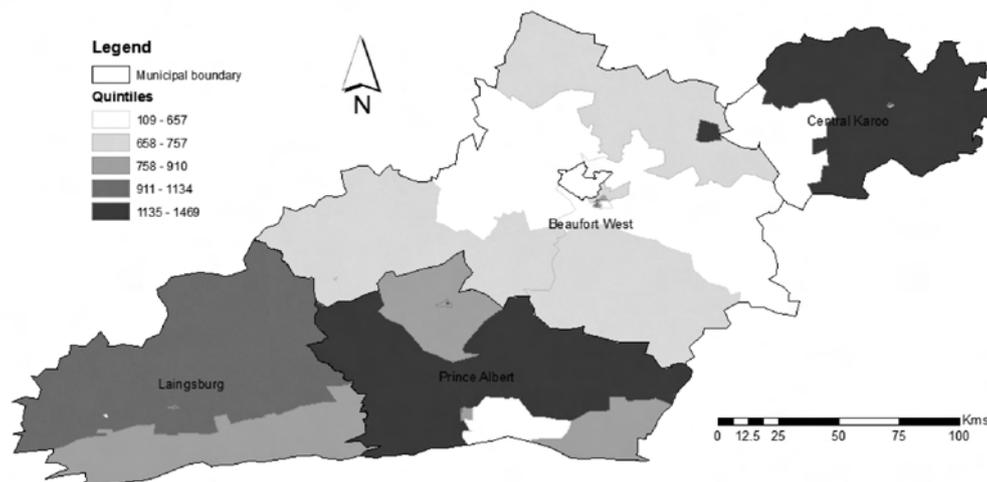
Our finding of relatively higher fatalities over evening hours and weekends is consistent with other studies in low- and middle-income countries (Odero et al., 1997). The elevated risks suggested by our findings may relate to higher alcohol-related deaths over these peak periods, as shown in a study of all alcohol and injury-related fatalities occurring in the city of Durban from 2001-2004 (Sukhai, 2005). The finding in this study of a large peak in fatalities over December appears to be anomalous given the observation by Sukhai (2005) of a relatively low percentage of alcohol-related deaths for this month (6%). However, greater mobility and exposure, in terms of higher leisure-related and migrant worker travel over this, and to a lesser extent, the Easter festive periods may be an important contributing factor. For example, findings from the RTMC (NDoT, 2007) showed the month of December (together with March and November) to have the highest percentages of fuel sales, which is suggestive of relatively higher traffic volumes and hence travel exposure during these months.

In terms of rurality, our study shows that the trend in traffic fatality risk across the urban-rural continuum to be non-linear but other clear associations are apparent. The vehicle-based fatality rate showed to be a better discriminator than the population-based fatality rate at differentiating rural-urban fatalities and showed highly urban areas in quartile 1 to have the lowest fatality rates.

The population-based rate showed less clear differential across the different indicators of rurality although higher mortality was apparent for urban areas when rurality was measured according to the percentage rural population and person-weighted population density measures. It is notable that the finding of higher road traffic fatality rates in urban areas was only apparent for urban areas located in quartile 2 of these measures. These DCs may be categorised as non-metropolitan urban areas that are sparse but with large clustered populations; suggesting that increased travel exposure may play a role in the heightened fatality risk in these areas. However, Central Karoo may have contributed to the high fatality rates in these urban areas. Central Karoo was ranked among the lowest ten DCs in terms of the number of fatalities but, with its exceptionally low population, it had a very high fatality rate of 114 per 100 000 population and could have inflated the rates for the quartiles in which it was located. Central Karoo was located in quartile 2 with percentage rural population and person-weighted population density measures (and quartile 4 with population size and population density), which were the same rurality quartiles that showed peaks in the population-based fatality rate.

Examination of Central Karoo highlights some of the difficulties in measuring rurality in this context and may also explain the weak correlations found between some of the rurality variables shown earlier. Figure 8 shows the population distribution by census Small Area for Central Karoo. The population are generally concentrated in a few Small Areas, mostly due to the area's large semi-desert and uninhabitable areas. With having more sparsely than densely populated Small Areas (and Main Places), the average population size is very low and hence, Central Karoo is considered highly rural (quartile 4) on this measure. A further difficulty is associated with differences in the physical size of the geographical areas being compared, which is especially important when delineating rural and urban areas. For example, in using the population size measure, Main Places in rural areas were on average two times bigger in terms of physical land area (636 versus 321 square kilometres) but the average population size was one-quarter times smaller (7 557 versus 29 067 people) when compared to urban areas. Compared with other DCs, Central Karoo has the lowest population of about 60 500; approximately half that of the DC with the second-lowest population (Namakwa).

Figure 8: Population distribution for Central Karoo District Council by census Small Area



With a very small population and a very large land area, Central Karoo has a very low crude population density and is also considered highly rural (quartile 4) on this measure. Hence the measure does not take account of the large areas of uninhabitable land that is included in the denominator of the measure but is not relevant to the population in the numerator. The use of this measure is therefore restricted, especially when the geographical areas being compared are characterised by large differences in population distributions. The very small population in Central Karoo are primarily (approximately 80%) urban, based on the census categorisation of rurality. Furthermore, when weighted by the large populations in the large census Small Areas, Central Karoo has a relatively high person-weighted population density (it is located in quartile 2) and hence is more appropriately considered urban, as compared to rural using the unweighted population density measure.

As a result of the significant weaknesses with the population size and crude population density measures, the percentage rural population and the person-weighted population density measures may be more reliable measures of rurality, at least in the South African setting. The percentage rural population measure has the advantage of capturing rurality at a very fine spatial resolution while the person-weighted population density takes cognisance of the arrangement of the settlement types and landscapes, which is an important consideration due to the large diversity of geographical areas in South Africa.

Although the population-based fatality rate did not show clear trends according to rurality, it was the only measure to show a distinctive difference between the pedestrian and non-pedestrian groups in the patterning of fatality rates across the rurality quartiles. The pedestrian group showed a slight decreasing trend with increasing rurality, in terms of the population-based fatality rate. Vehicle-based fatality rates were also shown to be higher for pedestrians in highly urban areas (quartile 1) than for non-pedestrians in highly urban areas. The relatively stronger link between pedestrian fatalities and urbanisation in our study is consistent with the heightened risk for pedestrians in urban environments reported by Petch and Henson (2000) amongst others.

The choice of denominators and difference in their magnitude between rural and urban areas has been shown to introduce a large amount of rural-urban variation in fatality rates in this study. Intuitively, we would anticipate the choice of denominator used to influence patterns of fatalities because, holding all other factors constant, areas with higher populations and more vehicles are expected to have more crashes and fatalities. However, areas with relatively high rates may be the result of an exceptionally low exposure in the denominator or an exceptionally high incidence of cases in the numerator of the rate. Rural areas are generally sparsely populated in terms of people and vehicles and would be expected to have higher population and vehicle-based fatality rates, although exceptions to this general trend were shown in our study. Higher vehicle-based fatality rates may also be due to the numerator representing an excessively high incidence of fatalities as a result of longer or more frequent journeys in rural areas.

Intuitively, road length may also be considered a potential denominator for comparing traffic fatality risk between areas. However, unlike the population and vehicle denominators,

areas with higher road lengths may not necessarily be associated with more crashes and fatalities. For example, areas with relatively high road lengths may have a higher fatality risk due to higher exposure from travel distances, but this may be offset by a lower risk if the probability of vehicle and person interactions is reduced in the more dispersed network. Hence, the relationship between road length and traffic fatality risk is unclear and the usefulness of the indicator may be questionable, especially in the absence of related travel exposure data.

## Conclusion

This study makes an initial contribution to the study of risk and geographical variations of road traffic deaths in South Africa. Important population-related risks have been demonstrated, and it is also clear that rurality is an important contextual consideration in the occurrence of road traffic deaths in South Africa. Studies that have examined rural-urban variations in road traffic deaths have often measured rurality solely based on population density, and traffic fatality risk according to population exposure. Furthermore, fatalities are rarely disaggregated by road user groups. Our findings would suggest that these approaches are restricted in showing just one dimension of several, and caution is necessary in order that biased conclusions are not drawn.

Further research should be undertaken to better understand the disparities shown in this study. In terms of risk, measures of traffic-related exposure should be expanded upon and disaggregated risk estimates such as for different temporal and seasonal groupings as well as for the different population and road user cohorts calculated. Further dimensions of rurality should also be examined, but with a more extensive range of environmental and demographic indicators included to more fully explain the broader geographical variations of road traffic deaths in South Africa. Additionally, South Africa's legacy of 'apartheid' that dictated place of residence and controlled the movement of people, may also have a significant impact on the distribution and magnitude of road traffic deaths in the country, and these largely unmeasured 'socio-ecological' effects should be investigated.

There is no single simple definition of risk or rurality since it depends largely on how the two indicators are measured as well as on the nature of data aggregation. However, the census-defined percentage rural population and the person-weighted population density measures were shown to be generally better measures for defining rurality in the South African context. Hence, caution is particularly important when risk and rural-urban criteria are used to guide policy and to allocate resources for road safety initiatives.

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ANESH SUKHAI  
School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk  
NR4 7TJ, UK  
E-mail: a.sukhai@uea.ac.uk,

Crime, Violence and Injury Lead Programme  
Medical Research Council  
P.O Box 70380  
Overport, Durban  
4067, South Africa  
E-mail: anesh.sukhai@mrc.ac.za

ANDY P. JONES  
School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk  
NR4 7TJ, UK  
E-mail: a.p.jones@uea.ac.uk

ROBIN HAYNES  
School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk  
NR4 7TJ, UK  
E-mail: r.haynes@uea.ac.uk