DIFFERENTIATED SPEED LIMITS THAT WILL WORK

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ABSTRACT

Following a research report (Van As and Joubert, 1998) and a fatal bus accident involving British tourists in 1999 the then Minister of Transport reduced the maximum speed limit for public transport vehicles (buses and minibus taxis) to 100km/h. This meant that light vehicles and public transport vehicles could have different speed limits on the same road – something that already applied to heavy vehicles.

The purpose of this paper is to determine the effectiveness of the different speed limits for different vehicle classes on the same road. The effectiveness is defined as the extent to which the drivers of the different types of vehicle keep to these limits.

The paper describes a project in which the free-flow speeds of different types of vehicle were measured on roads where the geometry was such that it did not affect the speeds. The speeds of nearly 9 000 vehicles were determined on 12 sections of two, four and six-lane roads in the Western and Eastern Cape Provinces where the general speed limit (ie for light vehicles) is 120 km/h.

It was found that 85% of the drivers of light vehicles and buses do keep to their respective limits, but that the drivers of heavy vehicles and minibus taxis to a large extent exceed their limits.

1 INTRODUCTION

Many road users in South Africa ignore the speed limit (RTMC, 2011). A very good example is that of the motoring editor of a Sunday newspaper who wrote an article (Sippel, 2011) on how he exceeded 200km/h on a two-lane National road in South Africa and this was not an isolated incident; he averaged 134km/h over a four hour period. The perception of many drivers seem to be that if the vehicle is expensive enough (R600 000+ in the above case) the speed limit does not serve a road safety purpose. A recent proposal from the Minister of Transport to decrease the maximum speed limit from 120km/h to 100km/h led to a public outcry. Other road users will argue that it is not so much the maximum speed that causes accidents but rather the difference in speeds and thereby try to shift the blame to those who prefer (or are forced by lower power-to-mass ratios or a differentiated speed limit) to travel at lower speeds.

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Speed limits can vary according to:

- The vehicle type;
- The time of day;
- The traffic conditions;
- Work zone activities;
- Weather conditions; and
- The lane in which the vehicle travels.

In this paper the different speed limits for different types of vehicle will be addressed and are referred to as differentiated speed limits. Following a research report (Van As and Joubert, 1998) and a fatal bus accident involving British tourists in 1999 the then Minister of Transport reduced the maximum speed limit for public transport vehicles (buses and minibus taxis) to 100km/h. This meant that light vehicles and public transport vehicles could have different speed limits on the same road – something that already applied to heavy vehicles (80km/h).

There are a number of reasons related to safety why different speed limits could be applied to different types of vehicle. As a result of the difference in mass, vehicles have different stopping distances – a basic feature in safe operations. Also related to the interaction between the tyres and the road surface is the ability of a vehicle to negotiate a horizontal curve. Excessive speeds can lead to a vehicle slipping or overturning on a sharp curve. Furthermore, different types of vehicle have different safety features, such as crumble zones, passenger restraints, electronic stability control, etc.

The application of differentiated speed limits is not without problems. The most important of these is the ability to enforce it. With the use of automatic speed cameras that cannot differentiate between vehicle types it is not possible to enforce more than one speed limit, with the result that the highest limit only is enforced. Speed cameras that are manually operated or have sophisticated apparatus with access to the SA vehicle data base (such as the speed-over-distance camera) will be necessary for the effective enforcement of differentiated speed limits. Another problem is the fact that international research has shown (Aarts and Van Schagen, 2006) that larger differences in speed between vehicles are related to a higher crash rate.

This paper describes a project (Marais, 2011) in which the free-flow speeds of different types of vehicle were measured to determine the effectiveness of the variable speed limits. In the following sections the reasons for differentiated speed limits for different vehicle types are discussed in detail, the methodology of data collection is described, the results are given and discussed and conclusions are drawn.

2 POSSIBLE REASONS FOR DIFFERENTIATED SPEED LIMITS

2.1 Stopping distances

The following formula (Papacostas and Prevedouros, 2005) is usually given for the calculation of the braking distance of a vehicle:

$$D_b = \frac{(v_0^2 - v^2)}{2g(f \pm G)}$$

For the stopping distance the reaction time multiplied by the speed should be added to the braking distance.

Where

D_b = Braking distance (m);
v_0 = Initial speed (m/s);
v = Final speed (0 m/s in the case of a stop);
g = Gravitational acceleration (m/s^2);
f = Friction coefficient; and
G = Gradient (%).

From this formula it is clear that the braking distance of vehicles should be the same irrespective of the mass of the vehicle. In practice, however, this is not the case since heavier vehicles need much better braking systems to fully make use of the available friction for the work necessary to reduce the large momentum of such vehicles at high speeds. The result has been that heavier vehicles (trucks and buses) have always had much longer stopping distances than light vehicles. This is clear from Table 1 provided by the Road Traffic Management Corporation (RTMC, 2005).

Table 1: Required Stopping Distance for all Vehicle Categories

Total Stopping Distance (m) Decision distance plus braking distance				
Speed km/h	**Small car**	**Medium car**	**Large car**	**Heavy vehicle**
60	60	66	77	116
70	78	86	101	154
80	99	109	129	197
90	121	135	159	246
100	146	163	193	300
110	174	193	230	359
120	203	227	271	424
130	235	263	314	495

SOURCE: Road Traffic Management Corporation, 2005

However, the introduction of antilock brakes has improved the braking performance of trucks. Research in the USA (Harwood et al, 2006) has shown that "*truck braking distances remain longer than passenger car braking distances on dry pavements. By contrast, on wet pavements, which are most critical to safety, the braking distances of trucks and passenger cars are nearly equal*". It is, therefore, clear that with the improvement of brake systems for trucks and the implementation thereof, the stopping distance criteria for differentiated speed limits is becoming less important.

2.2 Road curvature

The factors that play a role in vehicles slipping or overturning on sharp horizontal curves are super elevation and side friction in the case of the former; and height of the centre of gravity relative to the width of the vehicle in the case of the latter. In both cases the square of the speed is the determining factor and in South Africa where the speed limit on many roads exceeds the design speed, the road curvature is a factor in many accidents. Since the side friction and super elevation is the same for all vehicles, it is actually only the height of the centre of gravity that can be a reason for limiting the speed of certain vehicles. Trucks can be loaded such as to minimise the height of the centre of gravity but in the case of buses and minibus taxis (especially for double decker buses and when luggage is carried on the roof) this factor can play a major role in the decision to limit the speed of these vehicles.

2.3 Passenger protection

Modern private passenger vehicles have a range of safety features that are not present in the majority of public passenger transport vehicles in South Africa. These include seat belts, air bags, crumble zones, strengthened roof pillars (or roll bars in LDV's), brake assist, electronic stability control and many others. The European NCAP five-star rating for safety is well sought after in industry circles but is not applicable to buses and minibuses in South Africa. This is probably the main reason for limiting the speeds of buses and minibus taxis.

2.4 Safety performance

From the latest available South African data (RTMC, 2011) on accidents per vehicle type it is clear that buses, minibuses and trucks have a much higher crash rate per vehicle than the average. It is, however, also known that the distances travelled by these vehicles on roads where the general speed limit is higher than 80km/h is also much higher than the average. It can, therefore, not be concluded that these vehicles have a higher than average crash rate in terms of vehicle-kilometres travelled.

International research (Aarts and Van Schagen, 2006) has shown that the chance of being involved in an accident is much higher for a vehicle that moved (much) faster than other traffic around it. This is the basis of the argument that there should not be a speed limit differential (and thus travel speed differential) between heavy vehicles and other road vehicles (Ogden, 2006). After the general 55 mph (88 km/h) speed limit in the USA was lifted, some states implemented differential speed limits for cars and trucks. In all cases the differences in speed limits were either 5 or 10 mph (8 or 16 km/h), which is much less than the 20 to 40 km/h used in South Africa. After a number of research studies, (Harwood et al, 2006) it was concluded that differentiated speed limits have reduced the speed of trucks relative to passenger cars, but no accident reduction effect of differentiated speed limits has been demonstrated. Indeed, there is concern that by increasing speed variance, differentiated speed limits may increase overall accident rates. It should also be kept in mind that the effect of differential speeds on safety would by higher on two-lane, two-way roads where the opportunities for overtaking slower vehicles are limited (and more dangerous) as against multilane roads (two or more lanes per direction).

3 DATA COLLECTION

Vehicle speeds were collected in and around Cape Town, Paarl, Somerset West, Port Elizabeth and Motherwell. The data consist of the measured speeds of vehicles travelling in free flow conditions on a stretch of road that has a speed limit of 120km/h. Measurements were taken on relatively flat roads and not on roads with extreme gradients or curves to ensure that a true reflection of the desired vehicle speed was obtained. The speeds of four types of vehicle were recorded, namely light vehicles, minibus taxis, buses and heavy vehicles.

The apparatus used to measure the speeds of vehicles is the Bushnell velocity speed gun. The model is easy to use, it only requires that the user points the gun in the direction of the oncoming vehicle and holds in the trigger. Once the trigger is released the speed gun displays the measured speed onto the LCD digital screen. The gun is most accurate when directly in line with the vehicle and cannot store each speed. Once the trigger is pressed again the speed on the screen will be replaced by the next measured speed. Hence the user must record each speed manually before measuring another vehicle’s speed.

The following criteria were observed during data collection:

- The speed gun operator must be hidden to ensure drivers do not slow down when the operator is seen;
- Measurements must be done on a variety of days;
- Measurements must be done at different times of the day;
- Measurements can only be done on roads with a 120km/h speed limit; and
- Only the speeds of vehicles travelling in free flow conditions (only the first vehicle in a queue) were measured.

Twelve different sites were used for data collection: three on the N1 near Cape Town, one on the R300, six on the N2 near Cape Town and two on the N2 near Port Elizabeth. The speeds of a total of 8 987 vehicle were measured of which 6 279 were light vehicles, 1 110 were minibus taxis, 388 were buses and 1 210 were heavy vehicles. The range of vehicle numbers is indicative of the occurrence of the different types of vehicle that travelled at free flow conditions during the data collection. At each site a minimum of 30 vehicles of any type was observed.

4 RESULTS

4.1 Light vehicles

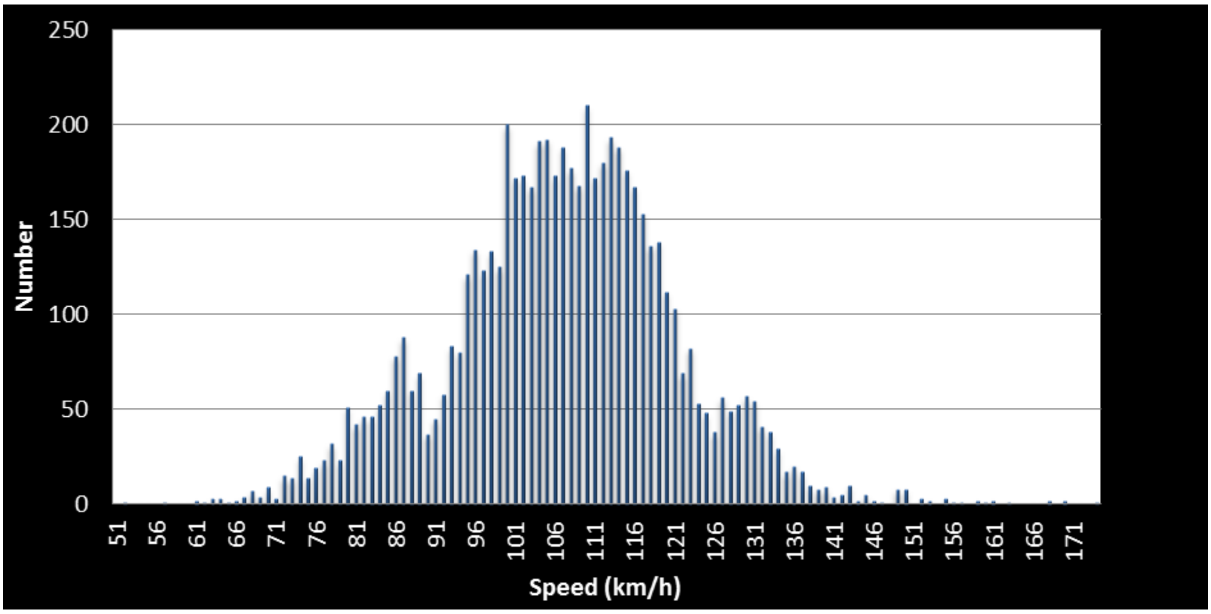

Figure 1: The frequency distribution of light vehicle speeds for all sites

The frequency distribution of the light vehicle speeds is shown in Figure 1. The speeds range from a minimum of 51 km/h to a maximum of 174 km/h. The average speed is 106.5 km/h and the standard deviation 14.3 km/h.

4.2 Minibus Taxis

The frequency distribution of minibus taxi speeds is shown in Figure 2. The speeds range from a minimum of 57 km/h to a maximum of 149 km/h. The average speed is 103.3 km/h and the standard deviation 13.7 km/h.

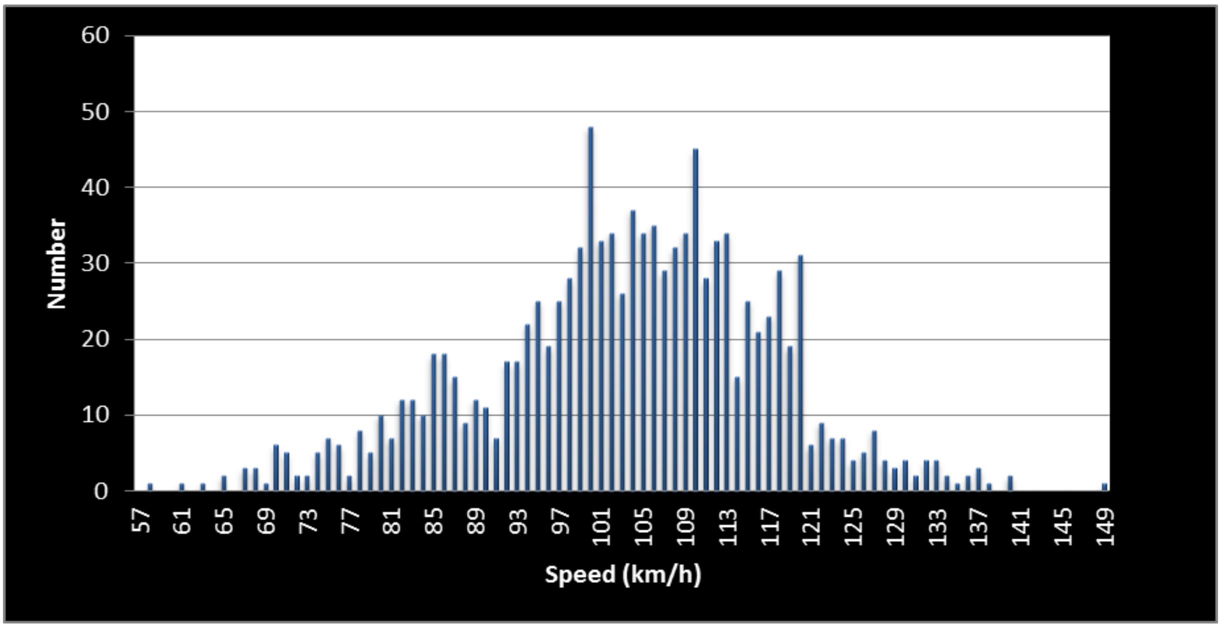

Figure 2: The frequency distribution of minibus taxi speeds for all sites

4.3 Buses

The frequency distribution of bus speeds is shown in Figure 3. The speeds range from a minimum of 44 km/h to a maximum of 128 km/h. The average speed is 87.5 km/h and the standard deviation 13.5 km/h.

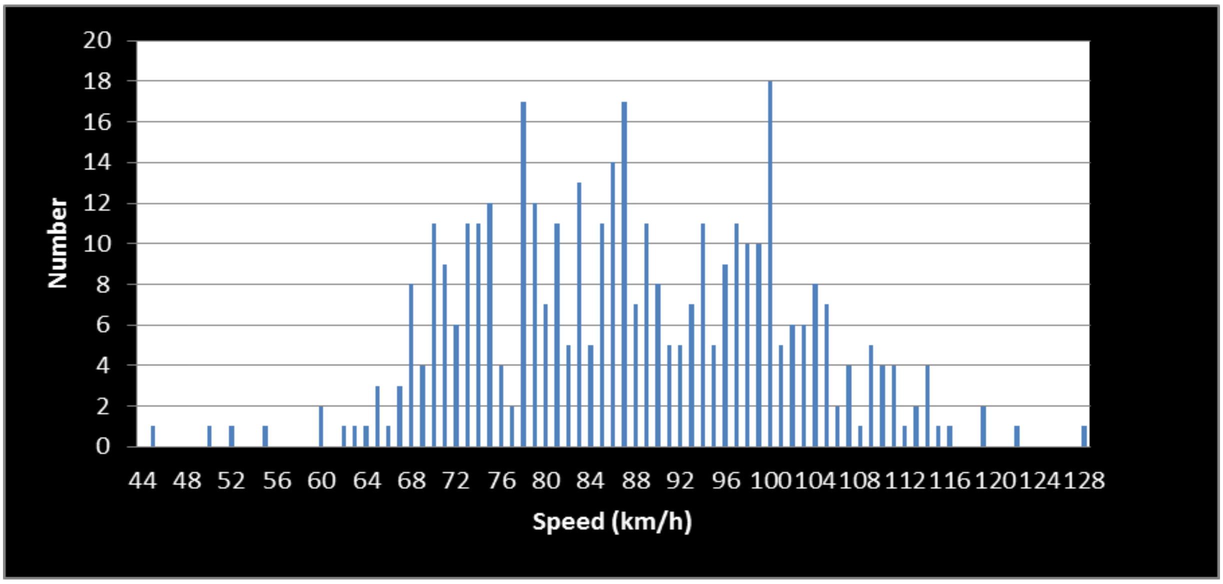

Figure 3: The frequency distribution of bus speeds for all sites

4.4 Heavy vehicles

The frequency distribution of heavy vehicle speeds is shown in Figure 4. The speeds range from a minimum of 40 km/h to a maximum of 121 km/h. The average speed is 85.5 km/h and the standard deviation 12.5 km/h.

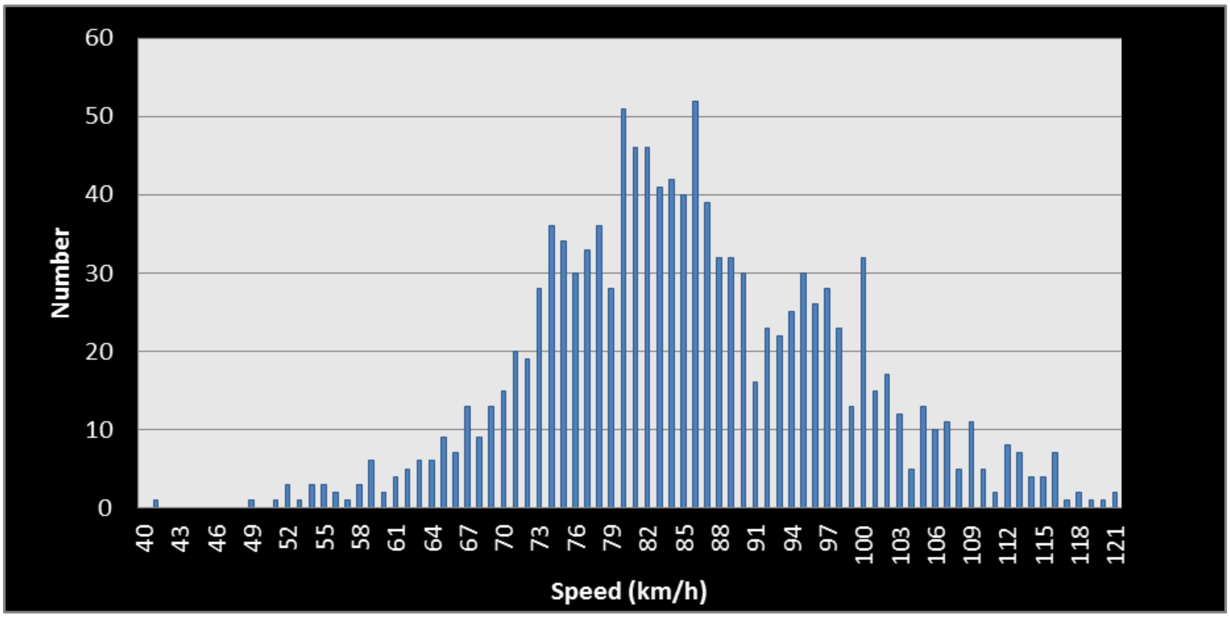

Figure 4: The frequency distribution of heavy vehicle speeds for all sites

4.5 Comparison with SANRAL data for the relevant national roads

A total of 23 counting stations from the South African National Roads Agency Ltd (SANRAL) were identified in the vicinity of the sites used for speed data collection. The average speeds of light and heavy vehicles have been recorded at these stations over a number of years and are used to validate the speeds collected in this study. Speeds of buses and minibuses are not measured separately at these stations. The comparison is shown in Table 2 where the data from this study is summarised.

Table 2: Summary of vehicle speeds (km/h)

Vehicle	Average	V_{85}*	Standard deviation	Range	% exceeding	SANRAL average Speeds
Light	106.5	120	14.3	51-174	14.9	103.8
Minibus Taxis	103.3	117	13.7	57-149	60.0	N/A
Buses	87.5	102	13.5	44-128	16.8	N/A
Heavies	85.5	99	12.5	40-121	64.0	83.9
All	102.9	118	16.8	40-174	26.5	102.5

V_{85} = 85th percentile

In both cases of light and heavy vehicles the average SANRAL speeds are slightly lower (2.7 and 1.6 km/h respectively) than the observed average speeds of this study. It should be kept in mind that the SANRAL data include minibuses with light vehicles and buses with heavy vehicles. Also, and arguably the main reason for the differences is the fact that the SANRAL data include all vehicles while this study concentrated on vehicles in free-flow conditions, where the speed of the vehicle is to a large extent determined by the choice of the driver. When drivers have to travel in a queue they usually do so at a slower than their preferred speed. It was therefore to be expected that the SANRAL speeds would be lower.

5 DISCUSSION

One of the widely recognised criteria for setting speed limits is to use the 85th percentile speed as measured on the specific road (Texas Department of Transport, 2012). It is, therefore, logical that the appropriateness of a speed limit (whether it works or not) for a specific type of vehicle can also be determined by means of the 85th percentile speed of those vehicles. From this point of view it is clear from Table 2 that the speed limits for minibus taxis (100 km/h) and heavy vehicles (80 km/h) are inappropriate. Also, when it is taken into account that more than 60% of these vehicles are exceeding the speed limit, it is clear that these limits should be reconsidered or at least enforced on a larger scale than is currently the case. If the limits are not enforced, there is clearly no justification for having them.

It is interesting to note that the buses are driven at very much the same speeds as heavy vehicles – on average 2 km/h faster – and this when their speed limit is 20km/h higher. One could say that a bus is a heavy vehicle. However, the legislation regarding the 80 km/h speed limit refers to heavy goods vehicles only. If then, for safety reasons, when people's lives are at stake why allow a higher speed limit for buses than for other heavy vehicles – or vice versa why force drivers of heavy goods vehicles to travel slower than heavy passenger vehicles? In answer to this question, some people could argue that the value of time is higher for passengers than for freight and, therefore, buses should be allowed higher speeds. This is, however, an economic decision and not one which relates to safety – the main reason given for speed limits. Economic decisions regarding vehicle travel should be taken by operators and not legislators.

From the data collected it is clear that the differentiated speed limits, as applied to South African roads, do not play a major role in the speed variability. More light vehicles are travelling at speeds lower than 92 km/h (the 15th percentile of light vehicle speeds) than any of the other vehicle types. This could be as a result of the age of our vehicle (or driver?) population. On the other hand, South Africa is one of a handful of countries where drivers are allowed to travel at 130 km/h on two-lane, two-way roads. Even though the maximum limit is 120km/h drivers are not prosecuted unless they travel at 131 km/h or more. To reduce the speed variance (average divided by the standard deviation) the only option will be to reduce the high speeds – there is no possibility to increase the low speeds. It can be shown, with the available data that should all vehicles travel at a maximum of 120 km/h, the average will decrease from 102.9 to 100.3 km/h and the standard deviation will decrease from 16.8 to 14.3 km/h. For this to be achieved, however, the maximum speed limit for all vehicles will have to be reduced to 110 km/h (because of the 10 km/h tolerance) and the speed limit will have to be enforced to a greater degree.

The fact that nine vehicles exceeding 150 km/h were observed, again highlights not only the fact that some people don't have any respect for speed limits, but that these are the vehicles more likely to precipitate collisions and where collision will certainly result in death.

6 CONCLUSIONS

From this project the following conclusions can be drawn:

- There are various arguments for and against the use of differentiated speed limits, based on vehicle type, to increase the safety on roads. In favour are those related to vehicle mass, handling and safety features or lack thereof. On the other hand is the effect of these limits on the speed variance, which was found to be detrimental to road safety. It is also difficult to effectively enforce different limits on the same road. American research has shown no safety benefits in differentiated speed limits although they investigated a maximum difference of 16 km/h.
- Minibus taxis and heavy vehicles do not adhere to their limits. More than 60% exceed the limit and their 85th percentile speeds are nearly 20 km/h higher than the limit. The purpose of these variable limits may be questioned because they clearly do not work.
- For buses the variable limit seems to work.
- Differentiated speed limits are not effectively enforced in South Africa.
- If the need for a lower speed variance can be demonstrated, it can only be done by reducing and enforcing the maximum speed limit.

7 RECOMMENDATIONS

For differentiated speed limits to work in South Africa it is essential that the current limits for different vehicles be reconsidered. When decisions are made on any speed limit or speed limit change it must be enforced effectively with intelligent cameras that can differentiate between vehicle types.

The maximum speed limit on South African two-lane two-way roads should be reconsidered to bring it in line with international practice.

8 ACKNOWLEDGEMENTS

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