AN EVALUATION OF THE BENEFITS OF INTELLIGENT SPEED ADAPTATION

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ABSTRACT

Road accidents claim between 13,000 and 14,000 lives annually in South Africa. The estimated costs due to Road safety problems is currently R38 billion. Speeding is one of the major contributors to the substantial number of road accident fatalities and injuries.

In Europe, the potential contribution of technology to the reduction of speed related fatalities and injuries have been researched over the past decade. Intelligent Speed Adaptation (ISA) is one of the systems investigated.

The potential benefits of ISA for the South African situation was quantified and costed by calculating the costs associated with speeding in terms of road accidents, vehicle operating costs, environmental costs, infrastructural and enforcement costs. The maximum savings that can be achieved by implementing ISA in South Africa was calculated as being between R18.7 billion and R51.2 billion annually. For both the minimum and maximum cost scenarios the additional vehicle operating costs as a result of speeding and the cost of road accidents are the greatest contributors to the total potential savings ISA could offer.

1. INTRODUCTION

The aim of the study was to find, list and quantify all of the benefits that Intelligent Speed Adaptation (ISA) might hold for South Africa. In addition, an attempt was made to provide an initial estimate of the cost savings that ISA could offer the country if it is implemented in full. The study took the form of a review of local and international studies to determine the various effects of excessive speed. Research into the effects of ISA and the application of ISA technologies was then applied to the findings regarding the effects of speed, and the results were used to determine what the potential benefits of ISA are for South Africa.

ISA encompasses the use of in-vehicle mechanical or electronic devices to physically control or limit a vehicle’s speed, or to warn or notify the driver when he has crossed a certain speed threshold. Different ISA systems can have varying levels of influence on a vehicles speed, and a number of systems have been developed that implements each of these different levels.

All forms of ISA are designed to influence the speed of a vehicle. Thus, the approach used in this study in order to evaluate the potential benefits of ISA was to first list and estimate the negative effects of speed, and then, by considering the extent that ISA can mitigate

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these effects, to ascertain what the potential benefits of ISA are. These quantities were then converted, where possible, to monetary equivalents and from this, the overall potential benefit of ISA was calculated.

Although there is generally an underreporting of accidents, and accident reports are often incomplete, the available data indicates that speed is the primary causal factor in nearly a third of all road accidents in South Africa, and is said to play a contributory role in approximately 75% of all road accidents[1]. This prevalence of speeding has negative effects on the economy, the environment and society in general. Much research has been done across the globe to determine these effects.

ISA has the potential to mitigate these effects by enforcing the posted speed limits. Furthermore, when combined with other intelligent transport systems, certain ISA systems offers greater control over road network utilisation by making it possible to actively influence average travel speed and, therefore, traffic flow volumes. This allows for more efficient network use and safer travel conditions on roads.

2. THE EFFECTIVENESS OF ISA SYSTEMS

ISA systems can have different levels of influence on a vehicles speed, depending upon the level of intervention used in the system. The level of intervention used in different ISA systems ranges from systems that simply warn the driver that he has crossed the speed limit with a visual or auditory notification, to systems that actively regulate the fuel supply to the engine to limit the vehicles speed. At an intermediate level are systems that use hydraulic mechanisms to apply a counterforce to the accelerator pedal once the vehicle crosses the speed limit. Other systems apply a gentle vibration to the accelerator pedal to notify the driver once he has crossed the speed limit. Certain systems allow the driver to disable or override the ISA system, whereas others do not. It is also possible to combine these ISA systems.

Further differentiation between systems is found in the method used to inform the ISA system of the prevailing speed limit. The simplest method is to limit the maximum speed that the vehicle can travel, with no consideration given to what the prevailing speed limit may be. A more advanced method is to use some form of removable media such as a compact disc that has been pre-programmed with the road networks speed limits. The vehicle is then tracked using Global Positioning System (GPS) technology similar to what is currently available for in-vehicle navigation systems. Other systems use radio transponders mounted on roadside furniture to inform the ISA system of the prevailing speed limit.

This array of technologies allows for substantial variations in the effectiveness of ISA systems in lowering speeds. In previous studies, this has often been weighed against the level of consumer acceptance as recorded from test subjects or user surveys. In general, the concern has been that the more intrusive ISA systems will have to face greater resistance from users, and that there could be legal implications regarding the use of ISA systems. In order to determine the potential benefits that ISA can offer, it was important to determine how effective the different systems were at lowering speeds. Two studies were considered and the data compared to reach a conclusion. Rook, Hogema and van der Horst (2005) published the results of two experiments carried out using different types of ISA systems. The experiments were designed to measure the effective drop in mean

[1] http://www.arrivealive.co.za/pages.asp?mc=speeding&nc=accidentsspeed

speeds over a given course in both urban and rural driving environments. The speed limit for both experiments was 80km/h. The experiments were:

An active gas pedal as a low-force ISA system. It produced a clearly distinguishable, and easy to overrule counter force when exceeding the speed limit, which was mainly informative in nature.

A tactile gas pedal that produced a clearly distinguishable vibration modulated by a block-signal when exceeding the speed limit for approximately 1 percent, which was mainly informative in nature.

The results that were obtained are shown in Table 1.

Table 1 Speed reduction due to ISA system

	Mean speeds (km/h)			Absolute Reduction (km/h)		Percentage Reduction (%)	
	Control	ISA 1	ISA 2	ISA 1	ISA 2	ISA 1	ISA 2
Active gas pedal	102	93.3	89.1	8.7	12.9	8.5	12.6
Tactile gas pedal	89.3	84.3	80	5	9.3	5.6	10.4

Source: Rook, Hogema and van der Horst, 2005

An earlier study by Hogema and Van der Horst (2000) was done on a driving simulator. The simulations were run to evaluate the effects of combining Automatic Cruise Control (ACC) with an ISA system. The ISA system was run on two levels, being informative (the driver is notified of the prevailing speed limits but can act as he sees fit) and intervening (the driver is notified of the prevailing speed limits and the ACC system reduces the speed to the appropriate level). The study considered three scenarios, these being:

- a 100 km/h speed limit for no reason
- an 80 km/h speed limit due to a relatively sharp curve
- a 50 km/h speed limit due to a sudden traffic queue

A simulation was also run for a standard free flowing motorway-style operating environment with a speed limit of 120km/h. The simulation yielded the results shown in Figure 1.

It was found that at the least intrusive level, such as that investigated by Hogema and van der Horst in the form of their purely informative ISA/ACC system, the speed reductions are negligible. A higher level or more intrusive form of ISA, such as the combination of the low force-tactile accelerator pedal ISA warning system, as discussed by Rook, Hogema and van der Horst, the results are improved. The average speed reduction measured here was between five and nine km/h. At the highest level, represented by the intervening ISA/ACC systems of Hogema and van der Horst, and the high force-dead throttle combination of Rook, Hogema and van der Horst, the results were found to be between 10 and 13 km/h in both studies.

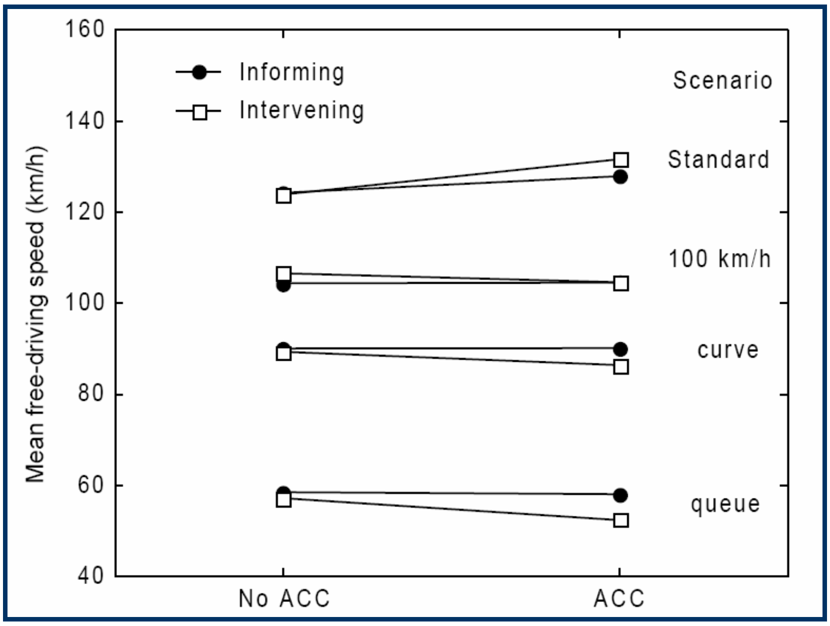

Figure 1 Mean free-driving speed as a function of presence of ACC and scenario
Source: Hogema and Van der Horst (2000)

3. THE COST OF ROAD ACCIDENTS

On average, 30-35 people die on South African roads each day, another 20 are permanently disabled and 100 are seriously injured. In 2005 there were 11 616 fatal accidents, a 10.9% increase on the 2004 total. The CSIR has estimated that road accidents have an overall annual cost equivalent to R38 billion[2]. Speed contributes for nearly one third of all road accidents in South Africa[3]. Applying the CSIR's figure of R38 billion gives an estimated cost of R11.4 billion annually, purely as a result of speeding motorists.

Several international studies were considered during this study. The most informative was the one from Barnett, Clough and McWha (1999), who conducted a study that outlines the methods used to quantify the social cost of road accidents. They noted that the costs of accidents could be divided or categorised in the following way:

- Real resource costs, such as the damage and consequent repair to vehicles and roadside structures; the opportunity cost of ambulance and traffic patrol staff and equipment attending to the scene of accidents; judicial costs incurred in prosecuting and imprisoning offenders; the costs of medical treatment and funeral services brought forward in time.
- Output costs, such as the productive work lost from individuals through accident-induced injury and impairment; accident-induced traffic delays; and transitional costs, such as costs incurred in recruiting and training replacement staff.
- Psychological and social costs, reflecting most individuals' aversion to risks to their own, or others', safety.

In addition, they noted that it is generally recognised that road accidents often cause significant disruptions to traffic flow. However, the probability of an accident, and hence of accident induced delays on any particular stretch of road, might be very low. On a national

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[2] http://www.finance.gov.za/documents/budget/2006/review/chapter%206.pdf; The 2006 budget review issued by the National Department of Finance of South Africa; ch 6; 2006
[3] http://www.arrivealive.co.za/pages.asp?mc=speeding&nc=accidentsspeed

or regional scale, the cumulative impact of accident-induced delays might be significant enough to warrant its inclusion in the calculation of accident costs to society as a whole.

When combined with the accident statistics for 1998 as given by the South African NDoT, the total cost of road accidents was calculated as shown in Table 3.

Table 3 Total cost of road accidents during 1998

	Killed	Seriously injured	Slightly injured
Number of cases	9068	36246	84358
Cost per injury	R 6,016,920	R 516,306	R 33,516
Totals	R 54,561,430,560.00	R 18,714,027,276.00	R 2,827,342,728.00

Summing the totals gives a figure of R76.1 billion. Applying the NDoT's estimate that speed accounts for approximately 30% of road accidents yields a value of R25,3 billion. It was noted that none of the estimates included costs incurred because of incident-induced congestion.

4. THE COST OF INCIDENT INDUCED CONGESTION DELAY

The cost of accident-induced congestion delay was found to be dependent upon a number of factors. Amongst these are:

- The costs associated with time delay due to congestion,
- The additional fuel consumed due to congestion,
- The additional operating costs due to congestion, and
- The additional environmental costs due to the congestion.

An investigation was done into these costs. The first exercise was to determine the extent of incident induced congestion delay. Two types of delay were considered. These were congestion near the incident in the same lane or carriageway and congestion in the opposing lane or carriageway because of "rubbernecking".

Findings from two American studies, that of Kwon, Mauch and Varaiya (2005) and Masinick and Teng (2004), were combined with South African accident statistics to estimate the extent of delay locally. A result of 291 972 920 vehicle hours annually was arrived at. A further finding was that "rubbernecking" accounted for two percent of the total delay. Moreover, an extrapolation of Canadian and American data, presented in a report by Shrank and Lomax (2005), showed that the total costs of the time delay due to incident induced congestion could amount to approximately R75,891,000 annually. If this value is combined with the total number of vehicle hours, this would equate to approximately R 0.26 per vehicle hour.

The cost of the additional fuel consumed as a result of incident induced congestion due to accidents, was calculated at R3,584,000 per year (R5.90/litre, 2005). This value was calculated from data presented by Tong, Hung, and Cheung in a 2000 study into fuel consumption and emissions levels in urban driving conditions.

The additional maintenance costs of vehicles, due to an incident-induced delay, was derived from National Department of Transport figures and calculated as a percentage of the fuel costs. The findings are shown in Table 5. These costs were found to increase the fuel costs by 64.7% bringing the total operating costs to R5,902,000.

Table 5 Maintenance costs as a percentage of fuel costs

	Servicing and repair costs (% of fuel costs)	Tyre Costs (% of fuel costs)	Total cost (c/km)
Petrol Vehicles	44.47	20.19	82.68
Diesel Vehicles	69.03	28.11	83.85

Source: http://www.finance.gov.za/documents/budget/2006/review/chapter%206.pdf;

The cost of the environmental damages, due to incident induced congestion caused by excessive speed, was calculated using empirical ratios defining the quantitative proportions of the major factors making up the costs of urban congestion, as derived in a 2006 study completed by Transport Canada. These ratios were compared and verified against similar ratios derived from data presented by Shrank and Lomax in their 2005 Urban Mobility Report. It was found that, in general, the following ratios could be said to apply:

- Time delay 90% of the cost of congestion,
- Fuel wastage 7% of the cost of congestion, and
- Emissions 3% of the cost of congestion.

Applying this ratio to the costs of time delay, as a result of incident induced congestion caused by accidents where speed was the primary contributing factor, yielded a cost of R 2,529,000. The total cost of incident-induced congestion was thus calculated as R 84 million annually.

5. THE ADDITIONAL OPERATING COSTS DUE TO EXCESSIVE SPEED

Radalj (2000) conducted a study to establish the baseline driver behaviour on roads with a 60km/h speed limit prior to the implementation of a blanket 50km/h speed limit. His study showed that the higher the order of a road, the greater the incidence of speeding. He found that between four and 10% of motorists exceeded the speed limit by more than 10km/h (figure 2).

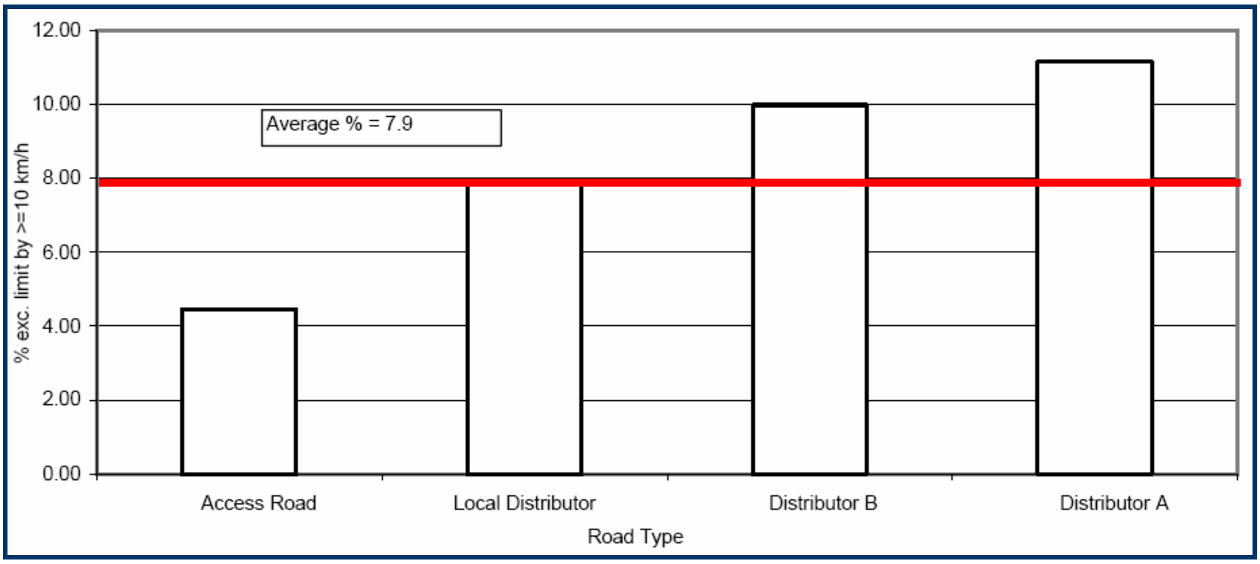
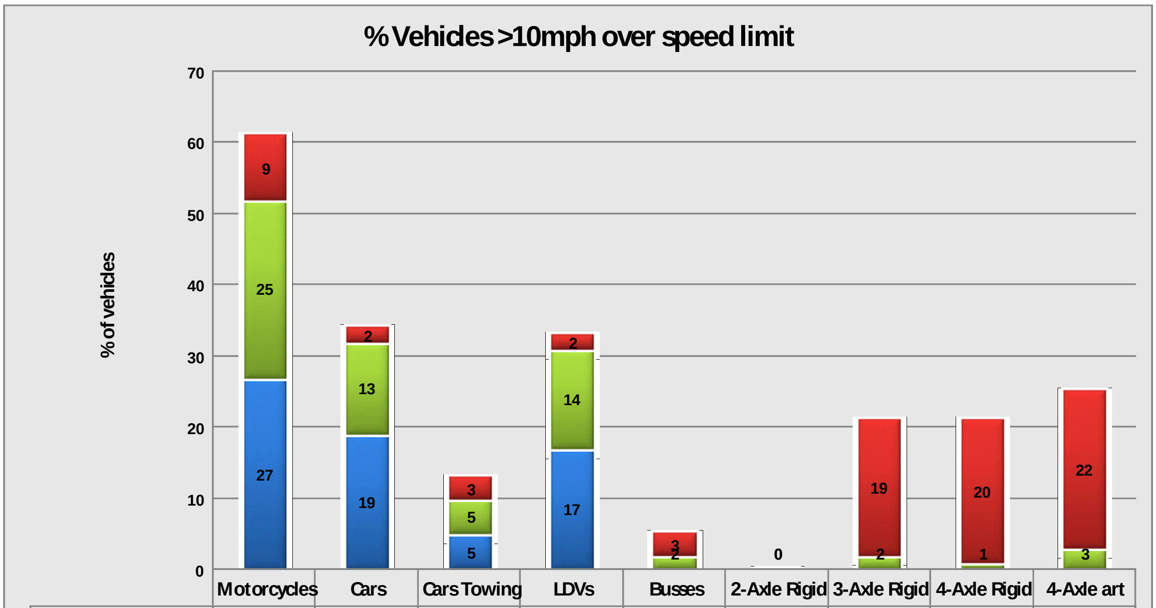


Figure 2 Vehicles exceeding the speed limit by 10 km/h on 60 km/h local roads
Source: Radalj (2000)

The findings on speeding of the UK Department of Transport in a study conducted during 2005 are summarised in the Figure 3.



	Motorcycles	Cars	Cars Towing	LDVs	Busses	2-Axle Rigid	3-Axle Rigid	4-Axle Rigid	4-Axle art
Single carriageways	9	2	3	2	3	0	19	20	22
Dual carriageways	25	13	5	14	2	0	2	1	3
Motorways	27	19	5	17					

Figure 3 Speeding by more then 10mph on different classes of UK roads
Source: UK Department of Transport, 2005

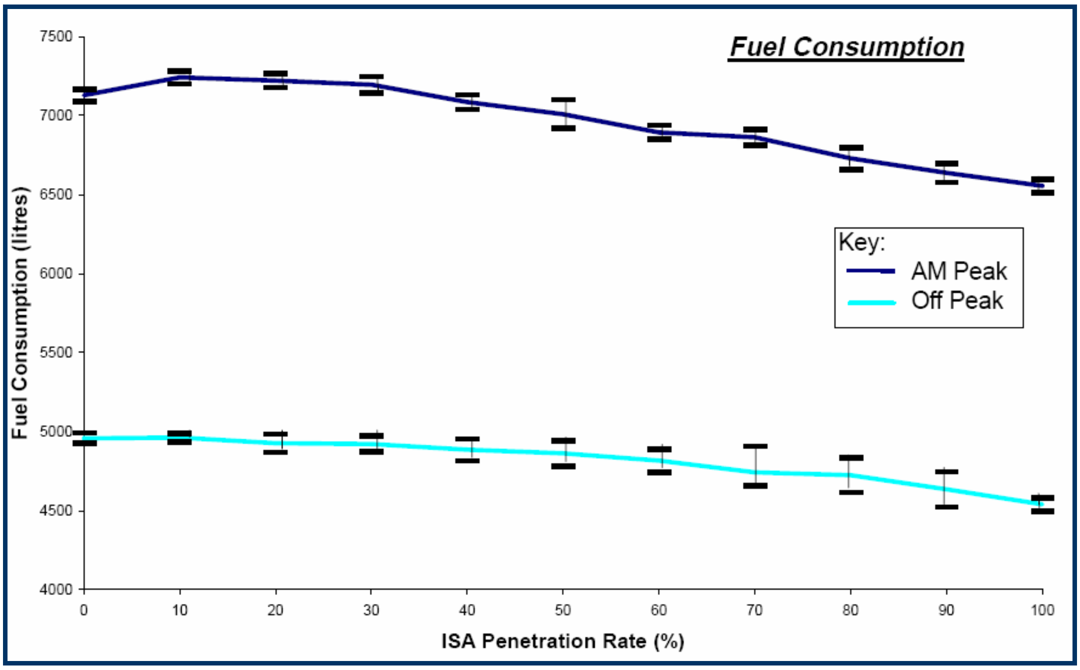


Figure 4 Fuel consumption as a function of ISA penetration rate
Source: Lui and Tate (2000)

It can be seen that motorcycles have the highest proportions of serious transgressors, and cars and LDV's are frequent serious transgressors on motorways and dual carriageways. Notably, a large percentage of heavy vehicles (on average 20 %) are speeding in excess of 10 mph above the speed limit. The conclusions that were drawn from these studies are as follows:

- The incidence of speeding increases the higher the category of the road.
- On average, between 20 and 50 % of vehicles travel at less than 10 km/h above the speed limit, and less than 10 % of vehicles travel at speeds greater than 10 km/h above the speed limit.

An eight percent fuel reduction was calculated in a paper by Lui and Tate (2000), which studied the effects of ISA using a micro simulation of an urban road network (Figure 4). The figure indicates that as the ISA penetration into the vehicle fleet increases, so the total fuel consumed decreases. This is because the average speed of the traffic flow decreases with an increase in the ISA penetration rate. The saving calculated using the data from this study was R 7.1 billion per year. The maintenance cost savings were calculated using the same method as discussed in Section 4. Applying this method to the two values derived for the additional fuel consumption costs results in a saving of between R 11.8 billion and R 14.2 billion.

6. THE ENVIRONMENTAL COSTS OF EXCESSIVE SPEED

An in-depth look into the relationship between vehicle speed and the effects on the environment was undertaken. This was done to determine to what extent ISA would either benefit or worsen the effect of automobiles on the environment. The question that needed to be answered was, accepting that ISA, even in its most severe application, could not eliminate vehicular emissions and pollution entirely, how would the elimination of speeding translate into a decrease in overall vehicular emissions?

A very comprehensive study by Delucchi et al (1998) was also considered. The study addresses a very wide range of the generalised impacts of automobile usage in the USA on the environment, and attempts to present its findings in US dollars. The results are presented as a range of values from low to high. An attempt was made to apply these findings to the South African context. This was done by multiplying Delucchi's results by various factors specifically derived for this report (Table 6).

Table 6 Conversion factors applied to Delucchi's findings

	GDP ($)	Vehicle Population	Population	Fuel consumption (l)
RSA	4.914E+11[4]	6875645[5]	44,344,136[6]	2.8087E+10[7]
US	1.175E+13[59]	248984865.8[8]	295,734,134[61]	1.78E+11[9]
RSA/US	0.041821277	0.027614711	0.14994595	0.1577936

The amended results are shown in Figure 5. It was found that the cost of automobile usage in South Africa on the environment ranged between R 4.61 billion and R 405 billion. The potential savings resulting from the introduction of ISA was presented for two cases. The first case assumed that 20% of motorists travelled in excess of the speed limit and the second case assumed that 50 % of motorists travelled in excess of the speed limit. These values were chosen based upon the findings of the UK and Australian studies (section 5).

[4] http://www.cia.gov/cia/publications/factbook/rankorder/2001rank.html
[5] Beukes, E; An Evaluation of the benefits of Intelligent Speed Adapatation; 2006; pg 45; UCT
[6] http://www.cia.gov/cia/publications/factbook/rankorder/2119rank.html
[7] http://www.cslforum.org/safrica.htm - assumption: one barrel holds 42 US gallons (standard crude oil barrel)
[8] http://www.manheimauctions.com/ucmr/us2.html - values adjusted to 2005 by applying an assumed 2% growth rate
[9] http://www.infoplease.com/ipa/A0004727.html

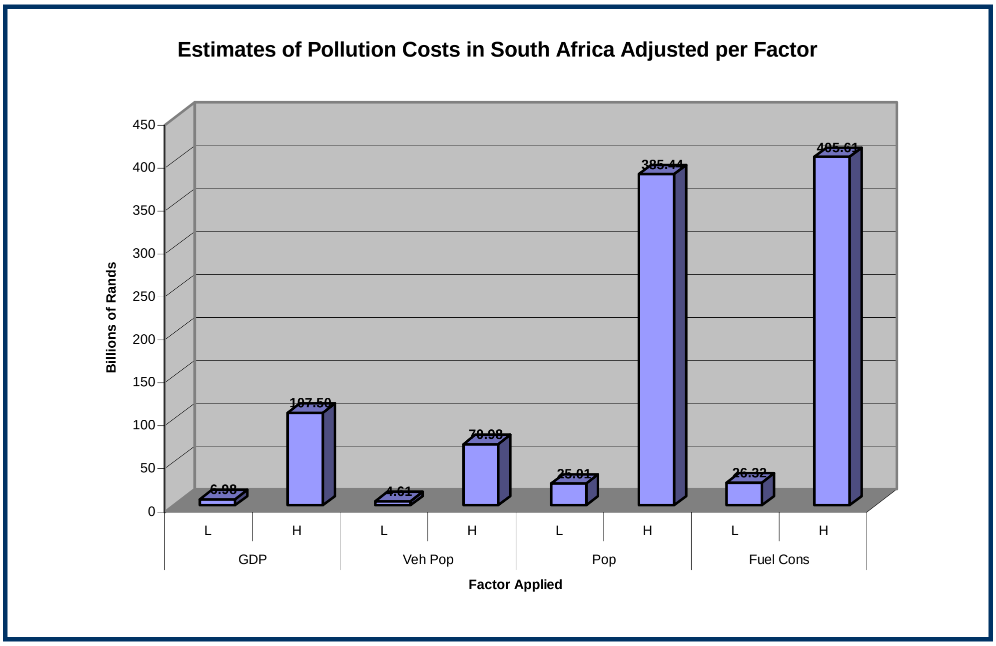


Figure 5 Estimates of Pollution Costs in South Africa

The results are presented in Table 7. The potential savings were calculated to be between R 48 million and R 10.4 billion annually.

Table 7 Potential emissions savings applied to Delucchi's results (R billions)

% motorists speeding	potential % emissions saving	Delucchi min	Delucchi max
20	1.04	0.048021	4.21875
50	2.56	0.118205	10.38462

7. INFRASTRUCTURE COSTS

The potential speed reduction due to ISA has the potential to reduce the cost of infrastructure that has been established to enforce speed limits. The cost of infrastructure established to enforce the speed limits was considered from two perspectives. Firstly, the cost of the administrative, labour and institutional infrastructure devoted to enforcing adherence to the speed limits, and secondly, the cost of the physical infrastructure installed to enforce the speed limits. It was found that nearly 50 % of resources devoted to traffic management went towards enforcing the speed limits. This finding was made based upon the proportion of fines issued for traffic offences. This finding translated into a cost of R 1.125 billion annually spent on enforcing the posted speed limits.

The scope of the physical infrastructure put in place to enforce speed limits was limited to speed cameras and traffic calming measures. It was not possible to determine the extent of the infrastructure that has been installed or is currently being installed. However, a cost benefit study undertaken by Hooke, Knox and Portas (1996) found that speed cameras cost £ 12,500 per site and that there was a recurrent annual cost of £ 8,500 per site. After converting to ZAR and applying an inflationary factor, it was estimated that a speed camera costs approximately R 265,000 to install and R 180,000 annually to operate and maintain.

8. CONCLUSIONS

The study has shown that a vast majority of costs can be identified that would be reduced due to the introduction of ISA. Table 8 provides a summary of the estimated savings. The overall maximum savings that can be achieved by implementing ISA in South Africa was calculated as R 51,2 billion per year and the overall minimum savings as R 18,7 billion per year.

Table 8 Summary of potential annual cost savings offered by ISA

Category	Cost Item	Value (million)
Road Accidents	Cost of road accidents caused by excessive speed	R 11 400
		R 5 622
		R 25 367
Time Delay	Costs of time delay as a result of accidents caused by excessive speed	R75.8
Operating costs	The additional vehicle operating costs because of incident-induced delay caused by incidents resulting from excessive speed	R 5.9
	The additional vehicle operating costs as a result of speeding	R 11 861
		R 14 225
Environmental Costs	The cost of damages to the environment because of incident-induced delay caused by incidents resulting from excessive speed	R 2.5
	The cost of damages to the environment because of the additional pollutants resulting from excessive speed	R 5 083
		R 6 096
		R 48
		R 10 400
Infrastructural Costs	The cost of the enforcement of speed limits	R 1 125
	The cost of infrastructure installed to enforce the speed limit	Unknown
Totals	Minimum	R 51 202
	Maximum	R 18 740

Under both scenario's, the additional operating costs as a result of speeding and the cost of road accidents, are the greatest contributors to the total potential savings ISA could offer. Together they contribute 93.3 % of the total savings in the maximum savings scenario and 77.3 % in the minimum savings scenario.

It can be concluded from this that by far the largest cost to the country because of speeding is due to the increased operating costs of vehicles and due to accidents caused by speeding motorists.

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