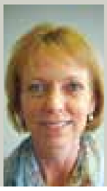
Efficacy of novel interventions on **speed compliance in the minibus taxi industry**

Akoku Ebot Eno Akpa
MEng Student 2014
Stellenbosch University
MTN Mobile Intelligence Lab
akokuenow@gmail.com

Dr Thinus Booysen
Department of Electrical and
Electronic Engineering
Stellenbosch University
mjbooysen@sun.ac.za

Prof Marion Sinclair
Department of Civil Engineering
Stellenbosch University
msinclair@sun.ac.za



BACKGROUND

The informal public transport industry, dominated by minibus taxis, accounts for a significant proportion of the collective transport market in South Africa. However, in-vehicle speed adaptive technologies are yet to be tested and fully implemented in this industry. According to national road traffic reports of South Africa most severe and fatal crashes are attributed to speeding, a significant number of which involve minibus taxis. A study carried out by the Automobile Association of South Africa recorded an annual total of 70 000 minibus taxi crashes, which indicates that taxis in South Africa account for twice the rate of crashes than all other passenger vehicles. Many of these taxis engage not only in urban trips on weekdays, but also in long-distance trips on weekends. Although the logistics of both types of trips (urban and long-distance) are different, the drivers and vehicles used are the same. Demographics revealed that most drivers engaged in long-distance transport fall within the age range of 31–40, with minibus driving experience being 3–5 years. In addition, these drivers work a minimum of six days per week, and spend 9–12 hours driving every day.

In the last decade a series of on-road Average Speed Enforcement (ASE) systems – commonly known as Average Speed Over Distance (ASOD) systems – were erected along notorious road sections. The use of ASE systems is growing steadily and gaining popularity in South Africa. Although it has been effective in general, a number of shortcomings are evident, specifically associated with the isolation of transportation modes in the evaluation process. Another countermeasure, not common to the informal public transport sector, is Intelligent Speed Adaptation (ISA), implemented through in-vehicle Human Machine Interfaces (HMIs). These ISA systems can continuously inform and enforce posted speed limits, unlike most on-road countermeasures which are spatially limited. In addition to these compliance enforcement measures, financial gain due to lower speeds could act as a non-invasive and inherent self-correcting incentive. This article explores ASE, ISA and fuel savings in the informal public transport sector in South Africa.

OBJECTIVE

The objective of the project was to compare and evaluate the efficiency of two state-of-the-art interventions (ASE and ISA) in improving speed compliance within the informal public transport industry in South Africa. The impact on fuel consumption was also evaluated as an inherent incentive that could act as a self-regulatory method on safety by increasing driver remuneration.

PROJECT DESCRIPTION

The project evaluated long-distance informal transport using minibus taxis between Cape Town in the Western Cape and Umtata in the Eastern Cape – a 2 400 km return journey, usually undertaken from Friday dusk to Monday dawn for religious and family ceremonies. The evaluation route was restricted to the 145 km section of the R61 between Beaufort West and Aberdeen. The first 71.6 km of the section from Beaufort West hosts one of South Africa's first ASE systems launched in November 2011, which we used as an Enforcement Route (ER). The rest of the section to Aberdeen was considered as a Control Route (CR). Figures 1(a) and 1(b) show the map and a section of the route.

Five Toyota Quantum minibus taxis running on diesel were fitted with fleet management devices that were sponsored and installed by MiX Telematics. These devices have integrated GPS reporting (speed and location), and audible speed-triggered warning tones which served as ISAs. The ISA systems were set remotely and triggered ten seconds after a fixed threshold speed of 110 km/h was exceeded. ASE fleet data was collected during the months of March and April 2014, while ISA fleet data was collected during the same months in 2015. Data validity was ensured by correlating average speeds calculated from GPS data with average speeds picked up by the ASOD system.

Fuel consumption was computed using the COPERT (Computer Programme for Emissions and Road Transport) model. This model – developed from European fleets – was considered appropriate for two reasons: first, South African vehicles have similar emission characteristics, and second, the only dynamic variable required is vehicle speed, which makes it easy to apply.

OUTCOMES

This section presents the outcome of each intervention on average speed, speed percentiles and speeding frequency. Mean speed was calculated as the average speed along each route as a function of distance and travel time. The proportion of the travel time spent driving above the ISA fixed speed, which we refer to as Speeding Frequency (SF), was also investigated.

Average speed and violations

An aggregate summary of key speed variables reveals significant differences between ASE and ISA, especially on the ASE Enforcement Route where average speed reduced by 7.7 km/h when ISA was introduced. In addition a 9 km/h reduction in 85th percentile speed was observed. Average speeding frequency also shows similar trends, with ASE having higher values in time and distance-based results for both routes. Effect sizes computed with respect to the intervention-free period on the control route were higher in magnitude when ISA was introduced.

A more detailed disaggregate analysis of mean speeds is shown in Figure 2 with 100 km/h and 110 km/h violation frequencies. Considering the maximum speed limit of 100 km/h, we observe that for both interventions over 90% of trips violate the system. On the other hand, the proportion of trips that violate the 110 km/h speed is low with ASE, but even lower with ISA. This shows that the ISA system is more effective at the set threshold speed of 110 km/h. Although the ASE system on the enforcement route has higher violation frequencies than ISA, there is nevertheless an improvement compared with violation frequencies on the control route with no intervention.

Figure 1: (a) Route map, and (b) Route section

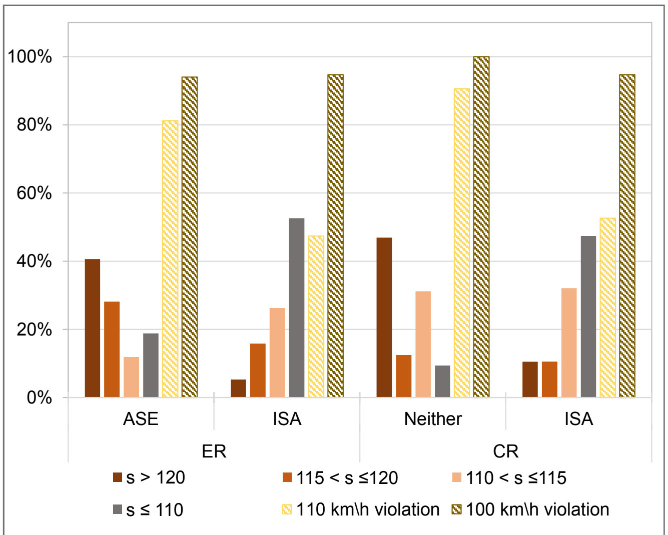


Figure 2: Speeding and system violation rates

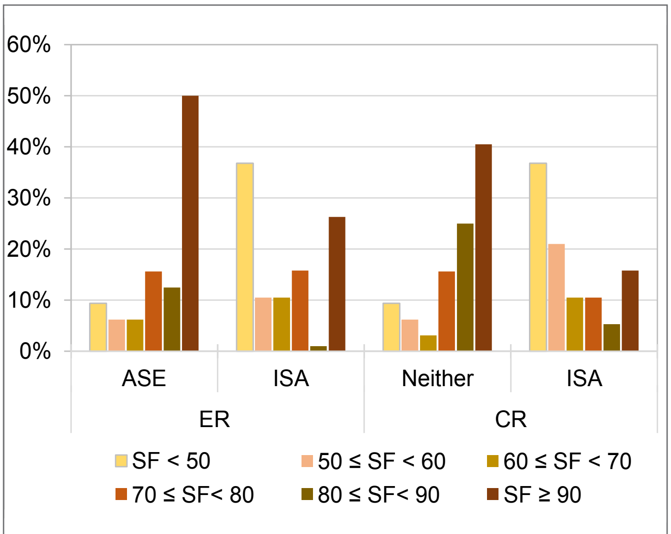


Figure 3: Speeding frequency

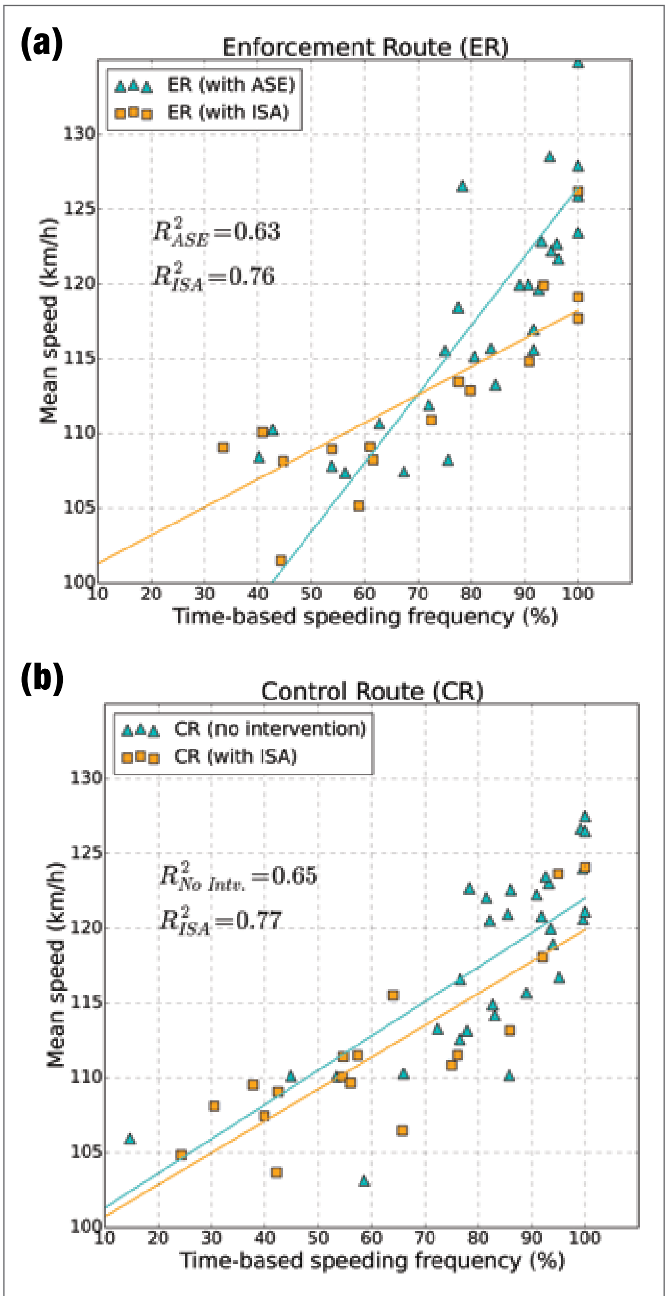


Figure 4: Mean speed versus speeding frequency on enforcement (a) and control (b) routes

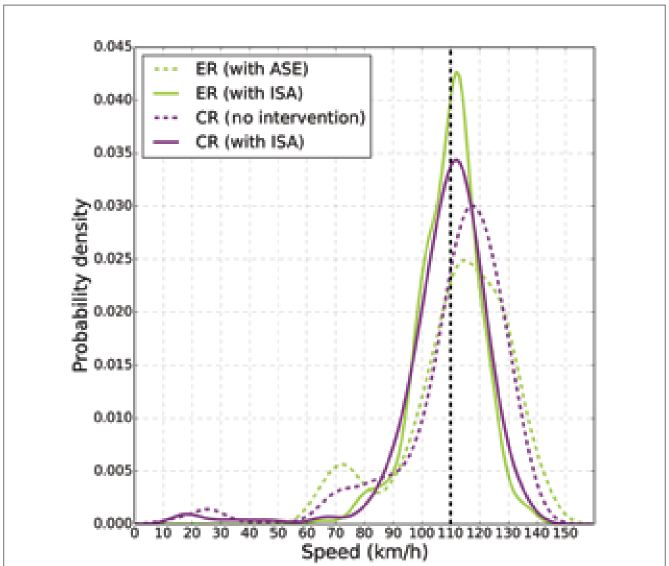


Figure 5: Results of speed distribution estimates

Speeding frequency

Time-based speeding frequency results are shown in Figure 3, with six intervals of interest for each intervention and route. The results show that with ASE alone, high speeding frequencies are more common on both the enforcement and control routes, but less so when ISA is introduced. Similarly, low speeding frequencies are more common when ISA is introduced, than with ASE alone. Furthermore, the relationship between mean speed and time-based speeding frequency is explored. In Figures 4(a) and 4(b) the scatter plots and regression lines on the enforcement and control routes for each intervention are shown. Individual trips are plotted as separate points. These plots show that the drivers are generally habitual speeders even in the presence of an intervention. This is evident from the presence of many points situated on the top right quadrant of the graph. On the enforcement route the ASE intervention has a steeper slope, indicating that introducing ISA was more effective in ensuring speed compliance. Similarly, on the control route, with no intervention, the slope is slightly higher than that of the ISA system. This occurs because, with no intervention, the control route had a higher proportion of trips with low speeding frequencies than the ASE intervention on the enforcement route.

Speeding distribution

Using Gaussian kernel functions, Kernel Density Estimation (KDE) with a suitable bandwidth was applied to estimate speed distributions. From the results in Figure 5, it can be observed that all four distributions are negatively skewed, with the ASE distributions being more negatively skewed, while all kurtosis values are leptokurtic (more positive than that of a normal distribution). More interestingly, with the introduction of ISA, the distribution means reduce on both routes, showing that ISA contributes towards speed compliance more than ASE. The high peak of both ISA distributions shows that the system had a compensatory effect on driving, especially around the ISA speed of 110 km/h. The slight deviation of the ISA distribution peaks from the 110 km/h mark is also evidence of the ten seconds time lag before buzzing is triggered. Results show that the ISA system is more effective at achieving speed compliance than ASE on both the enforcement and control routes.

Fuel consumption

Driving speed plays a significant role in fuel consumption. As a result, interventions to promote speed compliance can have the added benefit of lower fuel consumption. Using the COPERT model, fuel consumption estimates were computed for each trip through the control and enforcement routes. On the enforcement route, the computed average consumption rate was 8.35 km/ℓ for ASE and 8.58 km/ℓ with the ISA system. On the control route, the computed average consumption rate was 8.36 km/ℓ for no intervention and 8.63 km/ℓ with the ISA system. Compared to the control route with no intervention, ASE shows little or no change in the fuel consumption rate. However, with the ISA system, fuel consumption on the enforcement route improved by 3%.

Assuming that drivers keep to a 110 km/h speed limit, the maximum fuel consumption rate will be 8.2 km/ℓ (101.34 g/km), which happens to be the maximum rate for light-duty Euro II vehicles based on the COPERT model. This also explains why the ISA speed fixed at a 110 km/h does not result in remarkable reductions in fuel consumption rates.

However, comparing the fuel consumption of speed-compliant trips with the worst non-compliant trips reveals interesting results. With the ISA system active, some drivers were able to keep fuel consumption rates on the enforcement route as low as 10.1 km/ℓ, corresponding to a 1.74 km/ℓ (17.2%) improvement compared with the 8.36 km/ℓ average, and a 1.9 km/ℓ (18%) improvement compared with the 8.2 km/ℓ maximum rate. On the other hand, the minimum fuel consumption rate observed on the enforcement route with ASE is 8.76 km/ℓ which corresponds to a 5% improvement compared with the 8.36 km/ℓ average on the control route without enforcement, and a 6% improvement compared with the 8.2 km/ℓ maximum rate. For each trip, a driver typically gets R500 as payment, and a fixed fuel budget of R3 500 from the owner of the taxi. The 17.2% improvement in fuel consumption with the ISA system could result in an increase in driver remuneration by about 120% from the fuel budget. Also, the 5% improvement in fuel consumption with the ASE system could result in an increase in driver remuneration by about 35% from the fuel budget.

CONCLUSION

The objective of this article was to compare and evaluate the efficiency of automated ASE and auditory ISA on informal public transport. ASE was chosen because it has been installed and operational for a sufficient length of time for such evaluation to be run, and while ASE appears to reduce average speeds of conventional vehicles, our research indicates that it is less effective for minibus taxis. The potential of ISA systems to supplement ASE, or indeed to run as an alternative to ASE, was then tested. This was established by running analysis tools on GPS data collected on an ASE enforcement route, and an adjacent control route without ASE. A buzzing auditory ISA was activated at a fixed speed of 110 km/h for a month. Data analysis algorithms and tools were then used to collect and compare results.

The main finding was that, with regard to the minibus taxi industry, improved speed compliance can be achieved with ISA systems rather than through ASE alone. With the known proportionality between speed compliance and crash risk, this also implies that road safety can be improved with the parallel use of ISA systems. Previous investigation into low compliance associated with ASE showed that most minibus taxi drivers did not understand how the system operates and what was expected of them within the enforcement zone (Ebot Eno Akpa *et al* 2015).

Mean speeds, percentiles, speeding frequencies and speeding distributions measured on both the enforcement and control routes were similar, while ASE was active on the enforcement route. Not only were they similar, but they were characterised by high speed violation frequencies. Violation frequencies of 81.2% and 90.6% were measured on the enforcement and control routes respectively. This also shows that, despite the high violation frequencies, vehicles were more compliant on the enforcement route than on the control route, as would be expected. On the other hand, speed variables measured on both the enforcement and control routes were similar while the ISA system was active. However, in addition to the similarity, unlike the ASE intervention, average speed violation frequencies decreased, and were shown to comply closely with the ISA speed of 110 km/h. Violation frequencies of 47.4% and 52.6% were measured on the enforcement and control routes respectively. This is 33.8 percentage points less than violation frequencies with ASE on the enforcement route, and 38 percentage points less than violation frequencies on the control route. Over 90% of trips violated the 100 km/h legal speed limit for both ASE and ISA interventions. The improvement in compliance observed with the ISA system at a 110 km/h threshold suggests that an ISA system set at the actual speed limit of 100 km/h could also be influential in improving compliance.

Furthermore, the introduction of the ISA system not only improved speed compliance, but also reduced fuel consumption. Thus, for minibus taxis, ISA does not only provide safety as an incentive, but fuel economy as well. With the ISA system, fuel consumption rates as low as 10.1 km/ℓ (9.9 ℓ/100 km) were observed, while with the ASE system, low fuel consumption rates were around 8.76 km/ℓ (11.4 ℓ/100 km). Moreover, drivers can increase their remuneration by over 100% from the fixed fuel budget if they adhere to the speed limit. However, this does not seem to work as a self-regulatory incentive for compliance with speed limits and safe driving, probably because they are unaware of how much they could save, or simply because they are habitual speeders. There is therefore a need to train and educate minibus taxi drivers on fuel economy benefits.

It has been suggested that, to ensure high speed compliance, ASE systems cannot exist as the sole intervention (Soole *et al* 2013). The results in this article also confirm this assertion. In addition, poor driver understanding of the ASE system operation was identified as the main factor behind low speed compliance. The Western Cape government in South Africa experienced huge improvements in speed compliance as a result of this ASE system on the R61. However, from this study it is likely that minibus taxis which frequent this route do not contribute significantly to the observed improvements in compliance. This, therefore, suggests ISA technologies as supplementary interventions to existing ASE interventions, in addition to the need for driver education on ASE system operation. Moreover, implementing ISA technologies come with many advantages due to the ubiquitous nature of GPS data, and opens doors for more advanced implementation solutions. However, the hurdles of user acceptance of ISA systems need to be transcended, and further research needs to be done to narrow down system requirements which may lead to driver overloading or distraction. Nevertheless, the prospects of simplified auditory ISA technologies on safety improvement in the informal public transport sector are high, based on its positive effects in this small-scale study.

REFERENCES

Ebot Eno Akpa, N A, Booysen, M J & Sinclair, M 2015. A multimodal evaluation of the impact of Average Speed Enforcement (ASE) on road safety in the R61 in South Africa. Submitted to the *Journal of the South African Institution of Civil Engineering* and currently under review.

Soole, D W, Watson, B C & Fleiter, J J 2013. Effects of average speed enforcement on speed compliance and crashes: A review of the literature. *Accident Analysis & Prevention*, 54: 46–56. ◻

PROJECT TEAM/PARTNERS

MiX Telematics
SSML (Stellenbosch Smart Mobility Lab)
MTN Mobile Intelligence Lab