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An examination of potential exposure measures for vehicle safety technologies in South Australia

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TITLE

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ABSTRACT

Emerging vehicle safety technologies such as autonomous emergency braking (AEB) and lane keep assistance (LKA) systems are among a number of technologies for passenger vehicles that are likely to have a significant impact on road safety in the future. Their effects though, are highly dependent on those technologies becoming a more common feature in registered vehicles in South Australia (SA). While it is possible to monitor the prevalence of safety technologies on new vehicles sold in SA, a more involved process is required to determine the prevalence of these technologies in a representative sample in the SA registered vehicle fleet. A further, more complex issue is determining the ‘exposure’ of these new safety technologies on the SA road network. That is, even if it were possible to measure the number of registered vehicles in SA fitted with particular safety technologies, there is no accurate method to determine their likely effect until every registered vehicle in SA was fitted with that particular technology. Hence, while waiting for safety technologies to become a common feature of every registered vehicle, potential methods that might allow some degree of monitoring of the prevalence of safety technologies in the interim, are proposed and discussed in this report. While determining the prevalence of various technologies fitted on the registered vehicle fleet that is being driven on the SA road network is potentially feasible, the various processes are expensive and complex in nature, with sampling methods and on-going monitoring being most problematic.

KEYWORDS

Exposure, vehicle technologies, automatic number plate recognition, technology prevalence

Summary

Emerging vehicle safety technologies such as autonomous emergency braking (AEB) and lane keep assistance (LKA) systems are among a number of technologies for passenger vehicles that are likely to have a significant impact on road safety in the future.

Their effects though, are highly dependent on those technologies becoming a more common feature in registered vehicles in South Australia (SA). While it is possible to monitor the prevalence of safety technologies on new vehicles sold in SA, a more involved process is required to determine the prevalence of these technologies in a representative sample in the SA registered vehicle fleet.

A further, more complex issue is determining the ‘exposure’ of these new safety technologies on the SA road network. That is, even if it were possible to measure the number of registered vehicles in SA fitted with particular safety technologies, there is no accurate method to determine their likely effect until every registered vehicle in SA was fitted with that particular technology. Hence, while waiting for safety technologies to become a common feature of every registered vehicle, potential methods that might allow some degree of monitoring of the prevalence of safety technologies in the interim, are proposed and discussed in this report.

While determining the prevalence of various technologies fitted on the registered vehicle fleet that is being driven on the SA road network is potentially feasible, the various processes are expensive and complex in nature, with sampling methods and on-going monitoring being most problematic.

Contents

1 Introduction

There have been considerable changes to passenger vehicles in recent years that will potentially have a major impact on road safety. Active safety technologies such as anti-lock braking systems (ABS) and, more significantly, electronic stability control (ESC) systems (which is now a mandatory, regulated technology) are resulting in a decline in specific types of crashes (Scully & Newstead, 2008).

There has never been an adequate system for monitoring the effects of emerging or existing vehicle safety technologies on road crash numbers. Instead, research projects have generally been undertaken on an ad hoc basis. There are now significant changes coming about in vehicles, as levels of automation (Society of Automotive Engineers, 2014) are increasing from no automation (level 0), driver assistance (level 1), the introduction of partial autonomous vehicles (level 2), the possible introduction of increased automation (levels 3 and 4) to fully autonomous operation (level 5). Combined with this, is the changing fleet composition, different rates of vehicle attrition and a registered vehicle fleet which may look very different in the future, with decreasing crash rates due to improved safety technologies that assist with crash avoidance.

The purpose of this project is to determine whether it is feasible to measure the extent to which various new safety technologies have been deployed in the South Australian registered vehicle fleet. Of additional interest is the proportion of vehicle travel on the SA road network that is being undertaken using these 'safer vehicles'. Hence, in the context of this study, we are interested in determining methods to measure exposure for these types of vehicles.

Exposure is used in the context of the equation: number of crashes = crash rate x exposure. (See Appendix A, Appendix B and Hutchinson et al., 2009). Certain groups of drivers such as taxi drivers or truck drivers might have more crashes on average simply because they drive more. This is confirmed in the literature (summarised in Boucher et al., 2017), in that there is a relationship between crash risk for a driver and 'intensity of vehicle usage', such that higher numbers of vehicle kilometres travelled annually result in a higher number of crashes annually for a driver. Studies (summarised in Boucher et al., 2017) have found this result regardless of driver age and regardless of at-fault status.

Previous studies (e.g. Dutschke et al., 2017) have used prevalence of safety technologies derived from new car sales data, and then made assumptions to extrapolate the likely or expected uptake to a future time, where all new cars might have a particular safety technology installed. Different scenarios can then be considered to influence the saturation time point (where 100% of new vehicles have the technology fitted), including aggressive measures (making a technology mandatory), encouraged measures (ANCAP influence) or slow uptake (left to manufacturers). Further assumptions can then be made on how the new car sales prevalence of particular vehicle technologies will transfer into the general registered vehicle fleet. However, this method is based on predicting future uptake of technologies in new vehicles by assuming a similar uptake trend from a previous technology, without a solid basis for the prediction.

The benefits of monitoring exposure of vehicles with particular safety technologies in the registered vehicle fleet is that we can then monitor the effects and benefits of those technologies in the early stages of their uptake and as they start to increase in prevalence. By doing this we can determine whether mechanisms to increase their uptake and the likely benefits can be monitored, and then mechanisms to improve uptake in new cars can be optimised.

There are a significant number of safety technologies that may be worth monitoring. Based on the opinions of vehicle safety experts (Searson et al., 2015), those technologies believed to have the greatest impact on road deaths and injuries in the future, are listed below in Table 1.1. For each of these, Table 1.1 also lists the equivalent safety assist technology (SAT) being monitored as part of ANCAP's star rating process, as well as the IHS MarkitTM equivalent technology that can be returned during a vehicle identification number (VIN) decoding transaction.

This report will summarise various methods that could potentially be used to estimate how common certain vehicle safety technologies are in new vehicles, registered vehicles and in vehicles that are being driven on the transport network. Sampling issues, ethical issues and the likely costs of the proposed methods are also discussed.

Table 1.1
List of technologies worth monitoring

Technologies of benefit (Searson et al., 2015)	**ANCAP Safety Assist Technology equivalent being monitored**.	**IHS Markit™ equivalent** (previously called R.L. Polk Australia)
Autonomous emergency braking (AEB)	AEB City	Pre-crash/Collision safety system: Autonomous emergency braking
	AEB Inter-urban	
	AEB VRU	
Warning/intervention (lane keeping/departure, blind spot, speed relative to speed limit, reverse collision systems)	Lane Support Systems (LSS): Lane Keep Assist (LKA), Lane departure Warning (LDW)	Lane keeping assist system
	Blind Spot Monitoring Systems (BSM)	Blind spot warning system
	Speed Assist Systems (SAS) (auto/intelligent/manual speed limiter)	Not mentioned
	Speed Sign Recognition and Warning Systems (SSRW)	
Driver drowsiness/fatigue, distraction, or failure of concentration: detection and warning/intervention	Fatigue Detection (FD) Systems	Attention assist / Fatigue detection
	Fatigue Reminder (FR) Systems	
Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications	V2V and V2I	Not mentioned
Alcohol interlocks	Not currently considered	Not mentioned
Adaptive/advanced cruise control	Adaptive cruise control (ACC)	Cruise control - adaptive
Advanced lighting systems	Adaptive headlights, Automatic headlights, Automatic high beam, Day time running lights (DRL)	Active cornering headlight technology, Headlight beam height adjustment, auto, Daytime running lights
Autonomous vehicles	Not currently considered	Not mentioned
Autonomous braking when reversing	Reverse Collision Avoidance Systems (RCA): Reverse collision avoidance (auto brake), Reverse collision avoidance (camera)	Park distance control – rear Rear view camera
Automatic collision notification	Automatic emergency call (eCall)	Not mentioned
V2P: Vehicle-to-pedestrian communication systems	Not currently considered	Not mentioned
Night vision	Not currently considered	Not mentioned

Note that this report was substantially completed in December 2019 and does not consider developments or cost increases after that date.

2 Methods to determine prevalence of vehicle technologies in the vehicle fleet

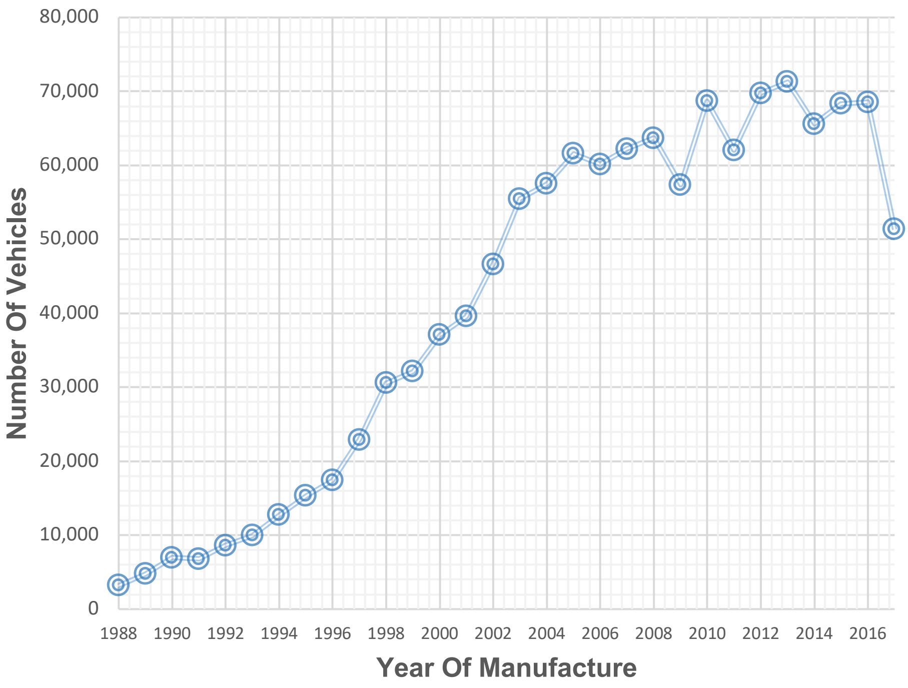
2.1 The registered vehicle fleet in South Australia

As of the first of January 2018 there were 1,277,946 passenger vehicles registered in South Australia, accounting for 71% of all registered vehicles in the state. Sedans and station wagons made up 83% of these passenger type vehicles, followed by utilities (13.5%), and vans (around 2%), with other types of vehicles accounting for fewer than 1%. Table 2.1 shows the number and proportion of registered passenger type vehicles in SA according to the year in which they were built. Most of the passenger type vehicles on register were built in 1988 or later (96.9% of all passenger type vehicles) and cars built in the last two five-year periods account for just over half of the registered passenger vehicle fleet. Figure 2.1 shows the number of registered passenger type vehicles for each build year since 1988.

Table 2.1
The number of registered passenger type vehicles for various build years in South Australia

Build year	Registered vehicles	Per cent
1988-1997	78,280	8.5
1998-2007	296,841	37.8
2008-2012	321,502	25.2
2013-2017	325,067	25.5
Total	1,021,690	96.9

Figure 2.1
The number of registered passenger type vehicles by build year in South Australia



2.2 Registration data analysis

Vehicle registration data is an extremely valuable resource that can be used to determine prevalence of safety vehicle technologies in the South Australian vehicle fleet. In its current form, data recorded consistently includes vehicle make, model, build date, registration plate number and VIN. Although a field for odometer reading exists, it is available for only about 12% to 15% of vehicles on register, and there is no information as to how often the odometer readings are filled in or how accurate they are.

Crash data is also a valuable resource and has always been used as a mechanism for determining crash risk, based on an estimate of general exposure. Anderson (2011) undertook a study in which he examined the safety attributes of the registered and crashed vehicle fleet in SA. The method used by Anderson (2011) was to take a random sample of 2000 passenger vehicles on register in South Australia (date stamped April 2010) and to record their safety features based on vehicle identification number decoding undertaken by a third party motor vehicle information service provider, IHS MarkitTM (previously called R.L. Polk Australia). Anderson (2011) found that, when comparing the safety attributes of registered vehicles to vehicles involved in casualty crashes in SA, the availability of particular technologies was generally similar among crashed vehicles and registered vehicles. However, electronic stability control (ESC) was found to be under-represented in crashes. This is not surprising, given that most of the technologies considered by Anderson (2011) were related to supplementary restraint systems (pre-tensioners, air-bags) and the only active safety systems were ABS, Traction Control and ESC.

Many safety technologies, though effective in relevant circumstances, have only small effects on the total number of crashes of the vehicles in which they are installed. Consequently, the prevalence of technologies in crashed vehicles may provide an acceptable estimate of their prevalence in vehicles being used on the road network, and in the registered fleet. However, some newer vehicle safety technologies may be very effective across quite a wide range of crash types; prevalence in crash vehicles would then underestimate prevalence in vehicles being used on the road network, and in the registered fleet.

Using registration data alone would be a satisfactory way of determining general prevalence of various vehicle safety technologies within the registered vehicle fleet. The process by which the registered vehicle fleet could be evaluated for prevalence of vehicle safety technologies (on a quarterly basis) is shown in the flow chart (Figure 2.2) below:

Figure 2.2
Flow chart of a potential process for determining quarterly updates of safety vehicle technologies in the vehicle fleet.

One issue with this process is that the association of safety technologies with a given model of vehicle is general in nature and not vehicle-specific. If a safety feature is optional, it will not be known if that option was taken up on a particular vehicle; the consequence of this is an under-reporting of vehicle safety technologies. The cost of such a process, without consideration of DIT registration data extraction, would be $20,000 per year. This cost consists of a vehicle information licence fee ($15,000 per year) and an additional minimum VIN transaction cost of $5,000 for 10,000 VIN matches and returns.

3 Methods for determining vehicle utilisation

3.1 Video recording and Automatic Number Plate Recognition (ANPR)

One of the methods that can be used to overcome issues relating to not knowing the registered vehicle utilisation rates is to deploy video cameras to film road traffic. This can be undertaken either on the road network or in car parks. Placing cameras at various locations around the traffic network or in car-parks would allow use of automatic number plate recognition (ANPR) systems to generate a database of number plates. These number plates, time stamped and location stamped, could be used as an alternate snap-shot sample of vehicles that are being driven on roads; that can be decoded by IHS MarkitTM, analysed and reported in the same manner as discussed previously.

The benefit of using this method, is that some degree of vehicle utilisation can be assumed, although a careful, representative sample design may be necessary to ensure good corresponding road traffic utilisation. Examining location of vehicle snap-shot compared to its registered garaging location may also give some indication of road network usage.

It's important to emphasise that careful thought is needed to ensure there is no significant sampling bias. Consistent and regular captures of vehicles entering or exiting from the CBD, entering or exiting the Adelaide and greater Adelaide metropolitan areas at different times of day may be a possible approach. Alternatively, monitoring the highest utilised road intersections or road networks is another approach. A large capture sample that can be split into sub-samples might give some idea how much variation between different conditions there might be. For example, three sites (all on arterial roads, one 2 km from city centre, one 20 km from city centre, one 200 km from city centre) and two times of day (day and night) might be a method to compare how different each sample is. Unfortunately, regardless of the approach taken, no video capture sampling will be a random sample and it will be difficult to validate how the sample might vary from a random sample.

3.1.1 Commercial ANPR systems

SmartSys Technologies offer a commercial system that can easily be deployed. A supported camera can be purchased for $750 (Axis T1435 LE Mk2, which has good low light recognition and has a manufacturer-reported 95% NPR rate). The licence fee per camera is $1000 (once off) with an additional per annum fee of $125. Actual number plate decoding is cloud based and the fee for this is $55 per month, with no minimum monthly subscription period required.

The process by which information would be derived is shown in Figure 3.1 below:

Figure 3.1
Flow chart of a potential process for determining quarterly updates of safety vehicle technologies in vehicles using the road network

A valid and repeatable sampling process to acquire the 2,500 vehicles per quarter for decoding, in the metropolitan area might work like this:

- Randomly select at least 20 locations, weighted by geographical distribution (e.g. north, south, east, west and a CBD location) for video deployment and recording for ANPR.
- The locations should include at least 5 major intersections, 5 minor intersections, 5 major and 5 minor road midblock sections and have meaningful traffic volume.
- A 24-hour sample of traffic conducted both on a weekday and a weekend should be collected.
- A random sample of 2,500 vehicles should then be selected from the pool of vehicles from the 20 locations but weighted by day of week (5:2 for week/weekend) and by traffic flow numbers at each location.

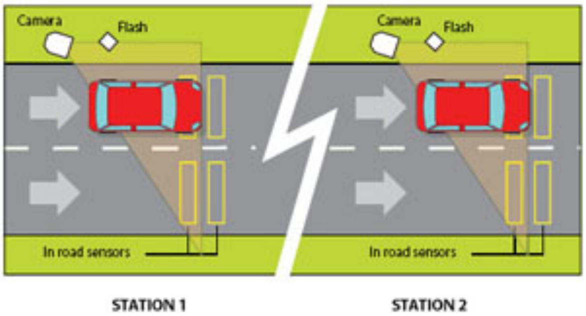
This process would then be repeated each quarter at the same locations as initially selected. Sampling in rural areas, may be more complex, but weighting by population distribution or traffic volumes might assist location selection.

3.1.2 Existing ANPR systems

Some car parks use ANPR systems, so this could be a source of data if there was cooperation with car park owners. Similarly, various Local Governments agencies employ services that have vehicle mounted ANPR systems that scan vehicles parked in various places. This could be another source of data, but perhaps even further from being random.

ANPR systems are already deployed by the South Australian Government, in the form of average speed safety cameras (see Figure 3.2). Presumably, such systems work by capturing images and time stamps of vehicles being driven through two fixed cameras, a known distance apart, at one of six locations (see below) on the SA road network at segments “of high risk, inner rural arterial roads, based on risk and exposure on a priority basis.” (Department of Planning, Transport and Infrastructure, n.d.)

Figure 3.2
Point to point average speed camera (image from Department of Planning, Transport and Infrastructure, n.d.)



The system matches (via ANRP capture) each vehicle passing through the two fixed cameras, and determines the duration of time taken for each vehicle to travel the known distance between the two fixed locations, to give the average speed of each vehicle. Number plates of the vehicles whose average speed exceeds the speed limit are retained (and those drivers fined) while the speed compliant vehicles’ number plate details are discarded. However, by retaining all number plates or a sample of number plates (speed compliant or otherwise), all cars travelling through the two cameras could be used as a sample of utilised vehicles for decoding by IHS MarkitTM.

Currently, average speed safety cameras are operational at six locations in South Australia (Department of Planning, Transport and Infrastructure, n.d):

- Port Wakefield Road (between Two Wells and Port Wakefield)
- Dukes Highway (between Ki Ki and Coonalpyn)
- Victor Harbor Road (between McLaren Vale and Willunga)
- Sturt Highway (between Wigley Flat and Lowbank)
- South Eastern Freeway (between Mount Barker Summit and Callington)
- Northern Expressway (between Port Wakefield and Gawler)

The legality of this process would need to be investigated before pursuing this idea further.

3.1.3 Ethical aspects of ANPR

Any research undertaken by CASR involving people or their data, including observations and recording of vehicles in road traffic, requires The University of Adelaide's Human Research Ethics Committee (HREC) approval, even if there is no risk to the individuals being observed. If CASR were to collect/record data of road traffic, an application to the University's HREC may be required seeking an exemption from the requirement to obtain consent from individuals driving in their vehicles who are being observed/filmed.

As the data being collected is just number plate details which will be decoded by IHS MarkitTM, there are no personal identifying features that can be returned from those data transactions. Even if the study involved comparing the captured road traffic data to the registered vehicle database (to extract age of registered vehicle owner, location of normal garaging and other details not supplied from IHS MarkitTM), no personal identifying features of the driver would need to be extracted.

3.2 Determining vehicle exposure through pay as you drive (PAYD) insurance

Some vehicle insurance companies are implementing or considering PAYD insurance systems (summarised in Litman, 2011). This is where a driver's annual insurance premium cost is assessed by both a driver's crash risk rating (i.e. a rating based on driving experience, crash history or even safety features installed etc.) and by actual vehicle utilisation, based on measured kilometres travelled per year. This system rewards those who limit their driving distance (and hence exposure to crash risk), while charging higher insurance premiums to those who are at a higher crash risk because of their higher annual kilometres travelled. The measurement of annual distance travelled can be undertaken with technology, by using a GPS and telematics based 'black box' or by the insurance company undertaking vehicle odometer audits at annual insurance renewals (checking kilometres travelled, evidence of odometer tampering etc). The benefit of such a system is that vehicle exposure can be determined for each vehicle using the PAYD system. Additionally, each insurance company would have listings of safety features fitted to the vehicles they've insured and could match kilometres travelled to vehicles with particular safety features. Such a system widely deployed could be a very good source of exposure data. However, it will not yield any usable data for some time yet, if at all.

3.3 Determining vehicle exposure through online or phone surveys

Wundersitz and Hutchinson (2008) discuss various measures of exposure in South Australia, including the Metropolitan Adelaide Household Travel Survey and the Health Omnibus survey. Unfortunately, these surveys do not collect detailed information about the types and specifications of vehicles being driven. A phone survey may be a good way to obtain a random sample of drivers who could be asked about the types of vehicles they drive and the kilometres they travel. There may be issues with accuracy of the data being provided, especially if asking for estimates of exposure, or asking people to check their odometer readings while on the phone. This method may also be expensive.

A longitudinal on-line survey or postal survey may be cheaper, may give participants more time to complete the survey, and may result in better quality of data. Questions pertaining to vehicle make, model, year, odometer reading and registration data could be asked. Additionally, requesting information from service records for the two most recent services (with odometer readings and service dates) would allow calculation of kilometres travelled between services. Requests for safety technologies fitted to their vehicle (using the list provided in Table 1.1) and whether any of the technologies have ever been 'triggered' during their experience with the vehicle could also be asked. This would be a difficult process, particularly in trying to get a large, random and demographically representative sample with a good and on-going survey response rate.

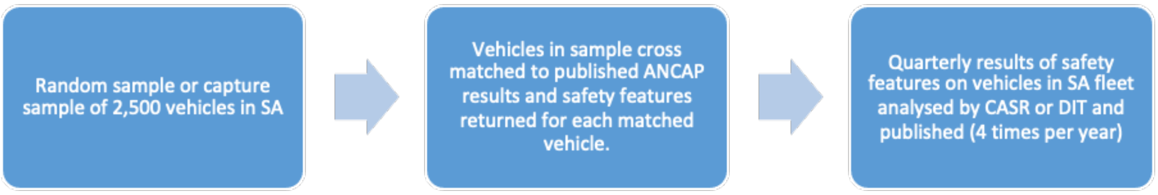
3.4 Alternative decoding of registration data to determine safety features

As shown in Table 1.1, ANCAP monitor and record the various safety features of interest when publishing the results of the tests undertaken on their behalf. ANCAP also undertake some analysis of vehicles being sold in Australia and have quite a significant vehicle safety feature database that could be used to estimate the prevalence of certain safety features in registered vehicles.

Consistent with ANCAP's desire to rate the most popular selling vehicles in Australia, ANCAP rated vehicles are presumably highly represented in the SA registered vehicle fleet. Consequently, there would be little difficulty in matching the make, model and build date of vehicles in the SA registered vehicle fleet database with ANCAP safety ratings and corresponding safety features for a majority of vehicles registered in SA. The benefit of using this method is that there will be little cost involved in acquiring the ANCAP data, although there will be some cost associated with trying to match the ANCAP safety data to the sample vehicle data.

The process by which vehicle information would be derived is shown in Figure 3.3 below.

Figure 3.3
Flow chart of a potential process for determining quarterly updates of safety vehicle technologies using ANCAP data to determine safety feature prevalence



This scenario could be tested against IHS MarkitTM data for one year to compare differences in estimating prevalence of various safety features for the same sample data.

The limitations of such a method is that not all vehicles are rated by ANCAP, so there may be some vehicles that will not be able to have their safety features decoded. Additionally, there are many variants of particular vehicle models. Therefore, if a safety feature is optional, it will not be known if that option was taken up on a particular vehicle in the sample being analysed; and hence the consequence of this is a conservative estimate of vehicle safety technologies in the vehicle sample that is being analysed.

4 Discussion

The change in prevalence of certain vehicle technologies (for example Autonomous Emergency Braking, Lane Keep Assist etc.) within the registered vehicle fleet in SA can be determined with some level of certainty and without too much difficulty. This can be done by taking a random sample of all passenger vehicles registered in SA, transferring the VINs or registration data to a third party and acquiring information regarding the presence of the vehicle technologies of interest in each of those vehicles in the sample. Repeating this process on a regular basis would allow analysis of the rate of progress for penetration of the technologies into the registered vehicle fleet and this is important from a safe systems point of view in terms of the monitoring of safer vehicles within the registered vehicle fleet.

The method by which this can be undertaken is outlined in this report. However, the issue with monitoring vehicle technologies by regular analyses of the registered passenger vehicle fleet is that there is no mechanism by which utilisation of the registered vehicles can be measured. There may be an assumption that vehicles highly represented in the SA registered vehicle fleet are also highly represented on the road traffic network in terms of utilisation or exposure, but unfortunately this assumption cannot be easily validated.

A suggestion has also been made in this report that the deployment of video cameras strategically around the state, at representative locations, could be undertaken to capture video of traffic on the SA road network. The analysis of this video with an ANPR system could produce a database of vehicle number plates that could also be transferred to a third party and information related to presence of the vehicle technologies of interest could be acquired for each of those vehicles in the sample. Again this process could be repeated on a regular basis to allow for analysis of the rate of progress of penetration of the technologies into the fleet.

The critical issue with this method is that, while the assumption of utilisation is somewhat validated (that is, we know the vehicles captured in this sample are being utilised on the road network), the sample may not be completely representative of all vehicles being driven on the SA transport network. Regardless, a suggested method is proposed for random sampling of locations and vehicle capture. A pilot study examining the feasibility of the proposed process and the results yielded, would be beneficial before committing to any long term monitoring.

Other more accurate measures of exposure, such as those using PAYD insurance systems via technological means or through annual odometer audits, would certainly give good measures of exposure for those vehicles utilising such PAYD systems but good exposure measurement would require every vehicle in the registered vehicle fleet to be monitored by such a system. This may well be a future scenario for insurance companies but is unlikely to be implemented widely through a regulated system of vehicle registration.

While this report discusses using a third party to ‘decode’ VIN or registration plate data, which is the easiest method of deriving vehicle technology information from a sample of vehicles, a potential alternative does exist. An estimate of likely vehicle technologies installed on a sample of vehicles (such as in the registered vehicle fleet) may be possible with the co-operation of the ANCAP, using make, model and year of vehicles being analysed. However, the results derived using ANCAP data would need to be compared against the results derived from a third party (for the same sample of vehicles) to ensure this is a valid method of ‘decoding’ vehicle safety features. It is also important to note that the data returned from the third-parties that decode VIN or registration details are general in nature, and may not be able to give precise information about the vehicle safety technologies fitted to the actual specific vehicles captured, due the methods used to decode the data. Consequently, the prevalence of technologies yielded in any analysis are likely to be underestimated.

Further, the confidence in detecting the 'real' prevalence of technologies will vary according to the Poisson distribution of counts and 95% confidence intervals for those counts, with the variability being N±1.96x√N. Since a sample of vehicles is being used there will be a certain level of uncertainty about how the sample reflects the general population of vehicles.

If the population has a 4% occurrence of a particular feature, a sample of 2500 would be expected to give a value in the range 3.2% to 4.8% about 95% of the time, with one sample in 20 expected to lie outside those limits. This limits the ability to compare one sampling period to the next. However, long term trends will start to appear once enough surveys are conducted. This effect is less of an issue (in proportional change terms) for features that are in closer to 50% of the population (95% confidence limits of 47.2% to 52.8% for a sample size of 2500). These uncertainties can be reduced by larger sample sizes but the reductions are very small for increased samples.

The primary focus of this report has been on describing methods that could be used to determine prevalence of vehicle technologies in the SA registered vehicle fleet and potential methods to overcome some of the issues relating to the inability to directly measure exposure or utilisation of these vehicles within the SA road network. Even if an ideal system were devised in which the exposure of each vehicle in the SA registered vehicle fleet could be measured, (i.e. kilometres travelled per year per individual registered vehicle), there are other complexities that need to be considered. Further detailed issues relating to the difficulties with the concept of exposure are discussed in Appendix A and Appendix B.

Finally, and while not discussed in the report, an ideal method for a registration analysis would be to require all details pertaining to the specifications of a vehicle (including safety features) to be submitted and incorporated within a vehicle's registration record when registered for the first time or re-registered in South Australia. This is not too different to the administrative task undertaken by insurance companies when assessing the value and risk of a vehicle being insured, although consideration needs to be given to the cost and burden of such a process.

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Appendix A – Difficulties with the concept of exposure

The concept of exposure

If different groups of people are found to have different numbers of crashes, should this be attributed to underlying differences in crash risk or differences in exposure to risk? When a question like this is asked, the term exposure is being used in the context of the equation number of crashes = rate □ exposure. For example, truck drivers may have more crashes per year than car drivers because they drive more, that is, their exposure is higher.

Two further conditions are likely to be the case. (a) The measure of exposure is something appropriate to the phrase "exposure to risk". It might, for example, be a count of the number of vehicles passing a point, or an estimate of the mileage travelled by a category of vehicle or a category of driver. (b) The rate that can be calculated as number of crashes / exposure is assumed to have a degree of validity or stability not possessed by the number of crashes. It is unlikely that rate would be regarded as satisfactory if the basic hypothesis (that number of crashes is proportional to exposure because rate is approximately stable) were considered implausible.

If there were an obviously satisfactory measure of exposure available, it would very likely be used. But that is usually not the case.

A straightforward example is that at road intersections, there are several flows of traffic, and it is not clear how to combine them in order to calculate an appropriate measure of exposure. Should we add the flows? Should we multiply the flows on the conflicting roads? Should we multiply the flows and take the square root?

Thus, we may often be in the situation that we consider the equation number of crashes = rate × exposure to be valid, but we do not know what exposure is. The multiplicative relationship does mean, though, that the number of one type of crash is proportional to the number of another type of crash. This is made more precise as follows.

- Suppose we write (in an obvious notation) Ni = Ri × Ei, where i refers to location on the road network.
- Let us also consider different years, which are referred to as j: Nij = Rij × Eij.
- Rate is thought of as a stable characteristic of the location i, and so is the same for all years, and Nij = Ri × Eij.
- Consider any two locations, i = 1 and i = 2, for example: N2j = N1j × (R2/R1) × (E2j/E1j).
- That is, the numbers of accidents at two locations are mutually proportional, provided that changes in exposure over the years are proportionately the same at the two locations. The rates R have been assumed to be stable, but the proportionality relationship still holds if they change in the same proportion (as they might do if vehicles are improving over time or if driver behaviour is improving over time).

The context above was that of comparing locations on the road network. Consider Nij = Rij × Eij again, but now suppose that i refers to driver age group, and j refers to model of car. Furthermore, the crashes counted in Nij are single-vehicle crashes. The first point to make is that it is unlikely that there is any data on mileage disaggregated by both driver age group and model of car. But, on the other hand, if there are a few years of data from a jurisdiction with a few million cars on the vehicle register, there are likely to be scores of crashes for a given combination of driver age group and model of car -

that will be sufficient to perceive patterns in the data, which is unlikely to be the case for combinations of location and year.

Risks of different people, at different places, of different vehicles, and in other contexts

Some individual drivers have what seems a lot of crashes, over a period of years. But are they genuinely risky drivers, per kilometre driven, or do they have a high exposure? This is typically not known, because there is no data on how far they drive.

On the positive side, it is quite common for results at a macro scale to be presented. But when more detail is required, difficulties become apparent very soon.

- In the case of young novice drivers, the evolution of crash rates on a scale of weeks (after gaining a licence) is likely to be of interest, but sample sizes in surveys of distances driven have not usually been sufficient to study such questions.
- In the case of elderly drivers, there may be special problems in gaining honest and correct responses, because of the risk of loss of licence on medical grounds.
- Capturing data on non-motorised modes of transport (e.g., walking and cycling) and on being on the road for purposes other than travel (e.g., recreation, working, playing) are perennial problems.

Distance driven makes no allowance for the conditions in which driving is done. Suppose that for one group of drivers, annual mileage averages 20000 miles, for another group annual mileage averages 10000 miles, and average number of accidents for the first group is 1.4 times that for the second group. The accident rate for the first group is 0.7 times that for the second group. However, it might be the case that driving by the first group is largely on relatively safe roads (e.g., motorways), and the lower accident rate is not attributable to the drivers themselves, but to the roads on which they drive. This known as the ‘Low Mileage Bias’ (Janke, 1991).

Are different crash rates associated with different elements of road design? Examples would include street lighting, pedestrian crossings, a centre median (central reservation), sealed vs. unsealed surface, shoulder sealing, the maintenance of the road surface, tidying the footpath to remove visual obstructions (and camouflage), and so on. And are different crash rates associated with different elements of intersection design? Examples would include gross design (roundabout vs. traffic signal; crossroads vs. offset junctions), skid-resistant surface treatment, phasing of traffic signals (such as the dangers of nonexclusive right turn between oncoming vehicles), cycle time of traffic signals, road markings, and so on. Unfortunately, it is unlikely to be possible to find exposure data that is sufficiently detailed and sufficiently compatible with crash data.

Some measures are directed at reducing exposure to risk without affecting amount of travel, and are not reflected in the usual measures of exposure. For example, railings prevent pedestrians venturing on to the carriageway for motor traffic, and traffic lights impose a separation in time on conflicting flows.

Is a specific intersection more dangerous than would be expected? The traffic flows on its several arms may be known, but it is not clear how these should be combined into a summary measure of exposure. But imagine that there exists a body of high quality research establishing that, say, the sum of flows is a better measure than the product of flows. Even in such a case, the research will probably have involved the comparison (perhaps via regression analysis) of numerous different intersections --- and it is not clear that good evidence about a broad-brush generalisation is any sort of evidence at all about what is appropriate for comparing a specific intersection with other intersections.

Are some models of car safer than others? Distances of travel by different models of car are generally not known even at an aggregated level. And it is likely that factors such as nature of ownership (fleet vs. private), age of driver, and circumstances in which they are driven (e.g., urban vs. rural) would have strong effects on crash rates, and these factors might not be independent of model --- with the consequence that differences between models could arise for spurious reasons. Disaggregating distance travelled by different models according to such risk factors is a step or two more difficult than the already difficult task of getting aggregate data for car models.

Consequently, it is often not possible to convincingly study whether crash rates are correlated even with such relatively simple characteristics as size, age of car, year of manufacture, front wheel drive vs. rear wheel drive, sedans vs. four wheel drives, ratio of height of centre of gravity to width of track, or having electronic stability control.

A lack of appropriate exposure data is likely to be found also when attempting to determine how dangerous various environmental conditions are (such as times of day, daylight vs. dark, and wet vs. dry), conditions of the driver (alcohol, drugs, fatigue, psychological states such as bad temper or feeling stressed), and behaviours (speeding, following distance, presence of passengers, use of mobile phone).

Aggregation problems

Accident rates are typically calculated at a highly aggregated level. It is possible for an aggregation paradox to occur (Wundersitz and Hutchinson, 2008).

- Suppose we want to compare accident rates in conditions A and B, and we have data for several subgroups. (The subgroups might refer to different geographical areas, or different times of the day, or different driver age groups, or other categories.)
- It can happen that accident rate is lower for condition A than for condition B in every subgroup, and yet accident rate is higher for condition A than for condition B when all subgroups are aggregated together.
- This phenomenon will occur when condition A occurs largely in association with subgroups having a high accident rate, and condition B occurs largely in association with subgroups having a low accident rate.

Such a misleading result at the aggregated level is likely to be very uncommon. The possibility is a warning that distortions do occur with aggregated data, and may be quite serious.

Optimism about the use of accident rates

Hutchinson, Wundersitz, et al. (2009) also expressed some optimism about the future usage of accident rates. They summed up by listing six reasons why the usefulness of exposure (and risk implied by exposure) may be greater in the future than in the past.

1. Availability of technology for tracking people and vehicles.
2. Availability of technology for visual recognition (e.g., of vehicle type or number plate).
3. Increasing practicability of linking different datasets (e.g., the crash, vehicle registration, and driver licence datasets).
4. Random sampling: if a sample is truly random, it does not need to be very big in order to give a good estimate of the population mean. The traffic and transport world has not really embraced the ideas of deciding what exactly is the population of interest and then taking a random sample. The traffic and transport world could choose to change, and use random sampling more widely.

5. Growing awareness of the importance of compatibility between transport and crash datasets.
6. The coordinated exploration of crash and exposure datasets with the ideas behind induced exposure kept in mind, without premature calculation of risk as the ratio of crashes to exposure, might throw up credible interpretations of why certain crash and exposure numbers co-vary while others do not.

Appendix B – The case against attempting to measure and use exposure

The following text discusses whether it is worthwhile to attempt to measure and use exposure.

Firstly, even the simplest process is quite difficult. The mechanics of taking a random sample of vehicles on the register, sending the VINs off for decoding, and receiving back data on whether the vehicle does or does not have each of several safety technologies might be thought straightforward, but it will probably not be known how frequently there are errors in VIN and in the decoded data, or the strength of any biases in failures to achieve decoding.

Secondly, supplementing that with data reflecting usage of vehicles on the road has another set of difficulties. If the data is obtained by observing registration plates, it is not known how to choose an appropriate sample of places at which to do this. It will probably not be known how frequently observations are in error, or how strong any biases in the process are.

Thirdly, the result is not quite what is wanted: usage on the road and distance driven are not the same as exposure to danger.

Fourthly, even if some measurement were available that better reflected exposure to danger, the difficulties identified in Appendix A suggest that it would not be easy to properly interpret the results.

We consider that the foregoing points are correct in indicating that it will not be easy to know how best to use exposure data or how accurate the figures are. It would be a mistake to expect too much from exposure data. Nevertheless, we would expect some positives to come from a process of monitoring how many vehicles have safety technologies. Just because the presence of biases in the data is plausible does not mean that they are so great as to make the figures valueless. Even if a sample is not random, it may give some insights into (for example) the types of conditions in which a vehicle is used, or the types of driver it has.