Towards an “intelligent” national road use management strategy

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Abstract

Increasingly sophisticated and affordable technology for roads and vehicles provides opportunity to conceptualise a national road use management strategy that exploits capabilities of intelligent systems. This paper outlines such a strategy that would enable for all vehicles, nation-wide, measurement, monitoring and reporting of data for driver information and education, safety, law enforcement, emergency response, research and other purposes with major safety and economic benefits. The concept includes installation of low cost data acquisition and communication units in all motor vehicles communicating with a central management system.

In-vehicle units, whether part of the strategy or vehicle-manufacturer supplied, would monitor vehicles’ location, velocity and acceleration, and transmit data only for safety, emergency, law enforcement and research, with appropriate privacy protection. The units would store road system data.

Continuous monitoring of every motor vehicle with appropriate algorithms would enable for all vehicles, nation-wide:

- highly intelligent law enforcement (e.g. average as well as instantaneous speed, red light infringement, etc.);
- immediate reporting of emergencies (e.g. excessive deceleration, overturning), even in remote locations;
- automated collection of tolls, parking fees and other access charges without collection infrastructure;
- flexible traffic regulation in congestion zones, residential zones, etc.;
- access management of specific vehicle types (e.g. dangerous goods, heavy vehicles);
- alerting drivers to hazards;
- ‘black box’ analysis;
- anonymous data collection for research, and potentially other applications.

The major challenges are in social and political arenas, because full benefit will be achieved only if the system is implemented universally, and that would give rise to significant social and privacy policy issues. These are discussed, along with implementation strategies, such as trialling with certain classes of vehicles, and further research directions.

1. Introduction

Death, injury and property damage on Australia's roads with consequent costs of major repair, support, rehabilitation and loss of productivity result in major economic and social costs. Although progress has been made to improve the safety of vehicles and roads, to educate drivers and to enforce the law, major personal, material and social costs continue to be incurred. Analysis by Risby et al 2010 indicated national social costs due to road accidents in 2006 were $17.85 billion, comprised of $3.8 billion due to fatalities, $6.7 billion due to injuries, $4.4 billion due to vehicle damage and unavailability and the rest due to congestion and delays caused by accidents, and vehicle-related insurance administration. Other estimates put the cost as high as $27 billion annually (Dept. of Infrastructure and Transport).

Telematics technology developments for monitoring the operation and performance of vehicles together with an increasing variety of in-vehicle sensors are opening many avenues for data collection, vehicle control and driver information, and, for example, enabling fleet control and safety management (e.g. NTC 2011 addresses freight sector issues and developments). These technologies will enable continuing improvement of road safety, driver education, emergency response and law enforcement, and data collection for research, but a major change of policy will be necessary to achieve the potential economic and social benefits.

I will discuss the basics of a national policy strategy that uses these technologies in at least a basic form in all vehicles, nation-wide, communicating with a central management system to achieve a broad range of education, safety, emergency response, law enforcement and research outcomes.

Other strategies are being trialled in various jurisdictions, such as Intelligent Speed Assist (ISA), which alerts drivers when they exceed the speed limit and may be used to intervene to control the vehicle speed (even smart phone Apps with ISA function—e.g. Metroview). Such developments go some way towards the concept of the proposed system, but potential outcomes of ISA fall far short of those of the strategy proposed, even though some studies have predicted as much as 20% reduction in casualty crashes when advisory ISA is implemented (Doecke et al 2011)

The strategy I propose would likely be opposed by some civil liberties and privacy advocates, and consequently this proposal might be dismissed on the grounds of insurmountable social and political barriers. I will address these issues after presenting the basic technical details.

2. Technical concept

The strategy would make as much use as feasible of exiting technology including telematics technology incorporated in vehicles by manufacturers. It would be highly desirable to work in partnership with manufacturers.

In the short term I expect it would be necessary to develop a basic in-vehicle unit for vehicles not equipped with necessary devices. The in-vehicle telematics unit (VTU), whether provided by the vehicle manufacturer or provided as a third-party unit as part of the strategy implementation, would have the following minimum capabilities.

- GPS for vehicle location;
- memory for map data, speed zones including temporary speed zones for road works and variable speed zones, and desirably other information such as toll zones, parking zones and congestion zone data;
- automated transmission of prescribed data to the central system;
- ability to present visual and audible information to the driver; and
- ability to compute in real-time the vehicle speed, acceleration and direction.

A central information management system would keep map data updated in vehicles and receive data from vehicles. The management system would interpret received data and provide notification to vehicle drivers and relevant authorities for action relating to emergency response, law enforcement, traffic regulation and hazard notification, and make (anonymous) data available for research.

The VTU would store vehicle speed, direction and acceleration internally according to criteria, such as for a specified time period. It would transmit data to the central system only if certain criteria were met. These criteria would include significant breaches of the law, detection of emergency situations and toll collection. Examples may include:

- the vehicle, once-off, substantially exceeding the speed limit;
- a pattern of the vehicle consistently exceeding the speed limit to a lesser degree than ‘substantial’;
- excessive deceleration or re-orientation (e.g. overturn) of the vehicle and other triggers from in-vehicle sensors such as triggering of airbags (refer Emergency Call Services), which would indicate that the vehicle may have been involved in an accident;
- data for automated collection of tolls, road tax and parking fees (e.g. in lieu of toll booths, electronic tag tolling, local parking fee collection, and data collection for congestion zone taxes); and
- erratic vehicle behaviour such as behaviour that might be characteristic of driver impairment and events such as ‘burn-out’ action by drivers.

The criteria and algorithms would include a definition of ‘substantial’—which might be different in different locations depending, for example, on the danger of exceeding the speed limit in different places due to current road, weather or traffic conditions—and ‘consistently exceeding’. Such criteria and algorithms would most likely require development through research and analysis during the development phase.

3. Implementation

Technology development is not likely to be a limiting factor in the strategy implementation, since use could be made of existing technologies in partnership with manufacturers. However, since this is an environment where great technical complexity is possible, though not necessary to achieve the benefits detailed in this paper, if realisation of the proposed strategy is accompanied by the development of substantially more complex technology than necessary the strategy might be derailed, or at least it might detract from the primary purpose of the strategy.

The major research and development effort would be in the development of a robust framework that was legally, ethically, politically and socially acceptable. This may include trials, perhaps with a particular class of vehicle, perhaps restricted geographically; for example, taxi services where the area of operation was fairly well defined, or buses or heavy vehicles.

Following the technology and framework development the strategy could not be implemented fully until all vehicles were fitted with VTUs, which could be done over two years by installing VTUs as part of the registration and annual re-registration of vehicles. While VTUs were being rolled out the strategy could be implemented on an information and data acquisition basis, and used for emergencies notification, but not for law enforcement.

The cost of the system and VTUs may be an on-going surcharge on registration charges, a one-off charge to vehicle owners, or a taxpayer-funded expense. If it was funded primarily by an on-going surcharge on registration charges, it could be set substantially less than the initial capital cost, because the initial cost could be spread over several years and calculated on a basis that includes ongoing system operation and maintenance.

A significant possible extension of the proposed strategy arises from the recent introduction of electronic licensing (Queensland Government, 2010). This opens an opportunity to interface licences with VTUs by requiring the VTUs to be swiped to enable vehicle operation, thereby linking the driver, not only the vehicle, to the information collected. It also would enable other options such as identifying whether the licence was valid for that particular vehicle type.

4. Privacy

Since the 1890s society has gradually come to regard the driving of cars and other vehicles as a right of every adult member of society. However, gradually freedom has been limited, particularly in recent years as technology advances have enabled increased monitoring, such as video surveillance and automatic number plate recognition (ANPR), and the use of such technologies for law enforcement as well as for charging such as toll collection.

So, many forms of monitoring and surveillance of the public are here to stay. The best that civil liberties and privacy advocates can hope for is that legal restraints on the use of data will be robust enough to protect citizens from unreasonable invasion of their privacy and rights. For example, the Australian Privacy Foundation addressed typical concerns (Australian Privacy Foundation 2008) in a submission relating the proposed introduction of ANPR in Queensland, concluding, amongst other things, that “use of ANPR represents an enormous interference with people’s legitimate expectation of privacy” and that “It is therefore critical that the purposes for which ANPR is being considered be defined. Any usage outside those purposes needs to be precluded by law.”

Such a privacy policy and legislative regime should apply also to the collection and use of data in the currently proposed strategy. Communication between VTUs and the central system, and use of collected data, should be placed under the supervision and control of a single national authority operating under privacy rules developed in accordance with privacy legislation and consideration of norms of society. This is an area that would require analysis and development, particularly considering the numerous state and federal authorities currently with an interest in and responsibility for road use and associated law enforcement. It would also be necessary to manage appropriately the privacy of data made available to commercial operators of toll roads, parking facilities, etc.

Permissible reasons for information communication with vehicle and/or driver identification could include:

- road rules law enforcement—reporting infringement of road rules;
- criminal law enforcement—reporting information or monitoring vehicles directly relevant to criminal activity;
- response to emergency situations—reporting excessive deceleration, overturning, erratic vehicle behaviour and other in-vehicle sensor triggers such as air bags;
- charging for road use—collecting toll data, parking data and data for other road use charges; and
- periodic test signals to confirm the functionally and accessibility of each in-vehicle unit.

And without vehicle or driver identification:

- alerting drivers of hazards ahead and advice to drivers relating to traffic congestion, road conditions and weather conditions—safety advice; and
- collecting anonymous data for research purposes;

5. User acceptance

Most likely it would greatly facilitate implementation if incentives were incorporated to enhance user acceptance. Examples could include:

- Reduced registration and reduced compulsory third party charges for safe driving patterns, and other non-financial safe driver rewards that could be noted on driving licences, for example.

- A VTU supplied where a suitable vehicle manufacturer unit was not available could incorporate a basic GPS-based navigation system. Potentially, this would have economic advantage, by enabling all drivers to navigate more efficiently and reliably, not only those with manufacturer-provided navigation systems.

- Fairer law enforcement. Instead of detecting speeding at particular locations (by road patrols, speed cameras, etc) continuous monitoring provides opportunity to apply algorithms that intelligently assess driving patterns and consequently enables fairer application of the law (see scenarios 2, 3 and 4 below).

- Systems to reduce driver stress. User resistance could occur because of increased pressure to avoid exceeding the speed limit while keeping close to the speed limit. To address this a speed controller that automatically keeps vehicles within speed limits could be made available as part of the strategy. By enabling drivers to avoid speeding while meeting most drivers' desire to drive close to the speed limit, such a controller would reduce driver stress. How would this work? Cruise controls keep a vehicle's speed constant, but this speed controller would enable normal vehicle operation at all speeds up to the speed limit, but not allow the vehicle to exceed the speed limit without override action. Since the VTU would 'know' the speed limit, the driver would not set the speed limit as with a normal cruise control. In an emergency the speed control could be overridden by action such a quick depression of the accelerator to enable travel at higher speed, returning to normal speed limiting operation after the vehicle slowed to below the speed limit. Such a unit could be used safely in all zones, inner city and urban as well as highway. Speed controllers providing essentially this function already are supplied as standard on some vehicles (such as "Speedtronic" by Mercedes Benz). This would not remove the driver's responsibility to pay attention to keeping within the speed limit, since, for example, the vehicle still could exceed the limit due to gravity when travelling downhill. However, it may have an added advantage of enabling travel consistently at the speed limit where it is safe to do so, rather than a little below, shortening travel times.

- A clear policy to put any revenue towards system cost and road safety. There is potential that public perception would be that revenue raising would be a significant factor in a decision to implement the proposed strategy. As noted by Johnston (2004), putting revenue raised towards system cost and road safety generally would likely change that perception. Johnston also notes that "We structure enforcement practice in an effort to minimise public reaction rather than to maximise the injury reduction outcomes and, in so doing, subvert the underpinning preventive strategy". Johnston concludes that "To win that support, we must first remove all those obstacles that we have created ourselves and secondly we must explain ourselves far better than we have done thus far."

The public acceptance and embracing of many monitoring and information exchange activities with the explosion of mobile communication devices might suggest that public acceptance of this system might not be a great obstacle. For example, car insurance "pay-as-you-drive" systems based on telematics are being offered by commercial insurers. These enable car insurance premiums to be determined on the basis of driving behaviours by using in-vehicle units that measure parameters such as time of travel, distance, types of roads used, speed, levels of acceleration and braking, and accidents, though some are based only on distance travelled. User acceptance of telematics devices for this purpose has been indicated by a survey (albeit probably not very rigorous) in the UK (gocompare.com, 2012), which reported that over half of 2000 drivers surveyed expect to switch to a telematics-based insurance policies within five years, and that drivers generally thought that these sorts of policies were much fairer. Reward was likely to be the major factor driving acceptance in this case, supporting the strategy of making reward an important part of the implementation of a universal telematics system. The system could interface with commercial insurers to facilitate pay-as-you-drive insurance products, thereby providing another incentive for user acceptance.

6. Anticipated outcomes

Reliable quantitative data on the contribution of speed to road accidents is not available, because comprehensive data about accident causes and consequences is not collected by police, hospitals or other authorities (Richardson 2008). However, some studies confirm the intuitive belief that speed is a very significant factor—in line with Isaac Newton's description in the 17th century of the motion of objects, as pointed out by Johnston (2004). Johnston's review of USA data clearly showed a strong correlation between speed limit changes and number of accidents during the 1970s to 1990s.

Effective monitoring and reporting of excess speed resulting in much greater adherence to speed limits should have the same general effect on road accidents as decreasing speed limits, while having no restraining effect on drivers that currently consistently keep within speed limits.

If the proposed strategy was implemented throughout Australia, the following are some of the anticipated outcomes.

- It should greatly reduce the incidence of exceeding speed limits, even in unpatrolled areas, because all drivers will know that their speed is being monitored against speed limits at all times and in all places, from inner city to remote outback;

- It would remove the need for most police patrols of roads, toll booths, E-Tags in vehicles, boom gates and other charging facilities at parking areas, much use of ANPR, and red-light cameras. The last of these could be achieved by local communication between a device installed at traffic lights and vehicles passing the traffic lights, infringements being recorded by vehicles' VTUs. This would require some technology development, but should be a low cost alternative to red-light cameras, enabling it to be installed on most or all traffic lights.

- It would immediately and automatically notify emergency services of most road accidents, even in remote areas.

- The system could contribute to initiatives to improve safety in other areas, such as safety at rail level crossings (e.g. National Rail Level Crossing Strategy) by enabling communication of the status of level crossings to drivers approaching crossings, thus complementing other warning systems.

- The system would provide an effective means of implementing road pricing with greater flexibility than is currently possible.

- The management of heavy vehicle regulations would be greatly facilitated.

- The system would enable management of areas restricted to authorised vehicles, such as some defence areas and access to off-road in areas such as in national parks.

- The system could supplant the need for intelligent speed assist systems, since it could provide the ISA functions and much more.

The anticipated reduction in road accidents should lead to major financial savings due to major and sustained reduction in road accident victims, reduced damage to vehicles and other property, less loss of productivity, reduced insurance administration costs, etc., since excess speed is a major contributor to road accidents: “Despite campaigns and strategies to the contrary, speeding and its consequences remain a major problem on Australia’s roads” Ellison and Greaves (2010). Ellison and Greaves found in a survey of 133 motorists in Sydney over several weeks that “20% of the moving distance travelled was above the posted speed limit, with a small but significant number of drivers regularly travelling more than 10 km/h above the speed limit.” This implies that the proposed strategy would have a major impact on driver behaviour.

7. Scenarios

The following scenarios indicate the extensive potential benefits of the strategy.

1. A car travelling on a little-used road overturns or collides with an obstacle and the driver is trapped in the vehicle. The VTU detects the overturning or sudden deceleration of the vehicle, or activation of airbags or other sensors, and immediately transmits that data and the vehicle’s location, which enables automatic notification of emergency services.

2. A driver travelling in a 100 km/h zone drifts 10 km/h over the speed limit, but does this only once and only briefly in a journey of 300 km, and in an area of relatively low hazard. If traffic police had been monitoring that section of road, the driver most likely would have been booked for speeding. However, the algorithm can be designed to assess the context of such infringement and make a fairer decision as to whether the driver should be booked or perhaps just warned.

3. A driver frequently exceeds the speed limit by 10 km/hr over a journey of 300 km, but is fortunate not to be speeding in the only area monitored by police at that time. The driver would not be booked. However, the VTU would detect the overall pattern of speeding and transmit information about the infringement.

4. In an urban area a driver has a driving pattern of frequently exceeding speed limits by about 5 km/hr. The traffic police have a policy of booking drivers only if they exceed the limit by at least 6 km/hr. However, the VTUs could detect this driving pattern as dangerous and initiate an infringement notice or a warning. As well, the driver could be alerted in real time to their hazardous pattern of driving, warning them that they were risking infringement action.

5. A traffic police officer detects a vehicle that had been used in criminal activity and pursues the vehicle, which becomes a high speed chase and ends in an accident where bystanders are injured or killed. With the proposed system, the vehicle’s movements are monitored without alerting the driver. That enables police to follow and locate the vehicle covertly, thereby avoiding a high speed chase.

6. Congestion tax legislation is introduced in certain city zones or the government desires to tax vehicles’ road use differently for different roads or sections of roads, and maybe different tax at different times. That information would be incorporated into the map data downloaded to all VTUs. The data could be used to apply the tax and, as well, alert drivers in real time to the tax applicable to their travel.

7. Temporary speed limits are imposed due to road works. The road works supervisor uses a hand-held GPS unit to upload the speed limit data, which is

then downloaded to all VTUs as a map update. Similarly, variable speed limit zones data could be downloaded to VTUs.

8. Instead of toll booths and electronic tags for toll collection, toll areas could be signposted, but have no other toll-collection infrastructure, Vehicles’ use of toll roads would be transmitted to the central system, because the toll locations data would be included in maps downloaded to VTUs. Drivers may then be charged directly if they have registered for a particular mode of payment, or drivers may be billed as currently for people that use electronic tag tolling areas without first registering.

9. Parking charges could be collected by using GPS to register the vehicle’s location for a measured period in a pay parking area. Boom gates, parking meters, etc could be eliminated, and charges made on the same basis as for toll roads. Similarly, parking infringements could be registered by using the vehicle’s GPS and time information. Sign posting of parking limits and charges would be necessary, as now, but money collection systems and monitoring by parking inspectors could be eliminated.

10. The VTUs could serve as ‘black boxes’ if they store vehicle location, speed, direction and time data for a period. Recent data could be stored permanently if an accident condition was detected. That would provide valuable data for the analysis of accidents.

11. Information sent to drivers could be displayed immediately or, if non-urgent, could be displayed after the vehicle came to a stop to avoid unnecessary distraction.

12. If traffic lights had localised signals corresponding to the state of the lights, VTUs could detect the state of the lights and monitor whether or not the vehicle moved through the intersection legally, thereby eliminating the need for expensive red-light cameras and providing a low cost option to expand the monitoring at traffic lights to more than currently covered by red light cameras. If this information was recorded in the black box mode of the VTUs, it would provide useful evidence in the case of accidents at traffic lights.

13. Disabling of speed limiting devices on heavy vehicles has led to prosecutions recently. Such devices could be replaced or complemented by the proposed VTUs. Since these would enable continuous monitoring and reporting, they should be much more effective.

14. Collection of data anonymous of personal information could provide extensive information for research purposes. For example, traffic counting equipment, currently placed at a very limited number of locations, would be superseded by the ability to count traffic at any location, even off-road, at any time, simply by interrogating the system. In addition, the data could be analysed by vehicle type as well as other parameters such as speed and time.

8. Conclusion

The national road use management strategy that I propose is technically easy.

There would be fewer risks to privacy and civil liberties than many current surveillance practices such as video surveillance and ANPR if lessons learned from existing surveillance practices were given adequate consideration in the strategy development, including control by an appropriately constituted national authority.

The strategy is a life-saving measure on a very large scale, and would achieve major financial savings, directly and indirectly, very likely in the billions of dollars annually.

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