The Future of Road Safety in a Technological World – How will technology impact the practice of Road Safety?

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Abstract

Over previous decades, road safety practitioners have delivered significantly safer roads through improvements in vehicles and by deploying countermeasures designed to reduce the risks that may be taken by a driver. Education and enforcement have sought to reduce driver risk taking, especially in areas of speed and drug and alcohol use. Behavioural studies and research data have provided evidence of the efficacy of various programmes and produced effective policy. Technology applied to vehicles has primarily focused on reducing injury severity in the event of a crash.

A new wave of technology is now upon us that is unlike previous technology. This new wave of technology seeks to further reduce the risk of fallible drivers by providing them with alerts or even bypassing them completely and controlling the vehicle to avoid a crash. Current systems of this type include Adaptive Cruise Control and embryonic Collision Avoidance Systems.

This wave has the potential to be game changing and very disruptive. The role of the driver is likely to change and ultimately there may be no need for a driver at all.

This paper examines what the future might hold for road users and presents a number of research questions for the Australian road safety community to consider. Discussion will include current technology, how the role of the driver may change, question how driver education may change, and what new risks might be introduced. This discussion will include a reflection on the practice of Road Safety with a changing road system.

Introduction

Safety on our roads has been a battle fought for decades. The ability of road safety practitioners to tackle road safety is often reliant on technical and technological improvements to vehicles, and to understanding and modifying driver behaviour. Two significant initiatives that have had great success locally are mandatory seat belt wearing and various programs to curb drink driving.

In this paper we reflect on previous great work of the Road Safety community. We then explore how current and future vehicle technology might impact on the current and future role of the driver. As we do this, we consider how these changes might impact on the current and future work of the Road Safety community.

Past and Current Road Safety Efforts (with a focus on vehicles and drivers)

The history of the practice of road safety is full of technological and practise innovations that have contributed significantly to the safety of road users. Vehicles themselves have changed appreciably over the decades. With a focus on crashworthiness, improvements in vehicles have reduced deaths and serious injury in the event of the crash. The modern vehicle is now designed to absorb energy and redirect forces away from occupants and tales abound of amazing "escapes" by occupants in

crashes at significant speed. Modern vehicles are clearly the best designed in history for protecting occupants in the case of a crash. However the market is showing signs that further improvements face the law of diminishing returns. Given fundamental physics, it is hard to see significant improvements in crashworthiness.

On a different front, significant progress has been made in understanding the driver's role in controlling a vehicle and mitigating risks that arise from having a human in control of a vehicle. Our understanding of how alcohol and drugs impair drivers and increase the risk of a crash has increased significantly. With a focus on education and enforcement, the previously entrenched behaviour of drink driving is now socially unacceptable and only practiced by a minority. Random breath testing in Australia has a clear correlation with a reduction in the road toll.

Speeding has also been a significant issue for road safety practitioners. While vehicles have improved significantly in their ability to absorb or deflect energy in a crash, fundamental physics cannot be escaped. The faster a vehicle goes, the more energy it carries, and the more energy that needs to be dissipated in a crash. Over the decades, the understanding of the risk of speed to the driver, vehicle occupants and other people sharing the road environment has matured. The consideration of appropriate speeds for driving environments has become an objective, evidence-based process. This is well understood within road safety and government circles, but perhaps unappreciated by many drivers.

Other initiatives target young drivers who are more likely to take risks. Elderly drivers are also known to present additional risks. Physical ailments and slowing cognitive abilities diminish an older driver's ability to react in emergency situations. Countermeasures such as testing older drivers and educating younger drivers are widely used to mitigate these risks.

Current Focus of Road Safety Practitioners

The past partly explains the current focus of road safety practitioners. If the program for the Australasian Road Safety Research, Policing and Education Conference, 2014 is an indication of the current focus of road safety, then current efforts have a strong focus on the driver. Topics such as young drivers, older drivers, driver impairment, speeding, driver behaviour, enforcement and education featured strongly. While areas such as road conditions, infrastructure, vehicle improvements and technology were present, the current focus is rightly on the role of drivers and the risks they introduce to the road system.

However, possibly the most significant recent innovation in road safety is the realisation that human error is inevitable. The *Safe Systems* (RTA 2011) approach to road safety recognises human error as unavoidable and the entire road system needs to mitigate the risk introduced by human error—especially driver error. This is something that technology has already started to address.

Recent Technological Improvements and Trends

A large array of technologies have recently become available in production vehicles. These include the following (Thakuriah & Geers, 2013):

- Adaptive Cruise Control (ACC)*

- Emergency Brake Assist *

- Forward Collision Warning

- Autonomous Emergency Braking *

- Electronic Stability Control (ESC)*

- Lane departure warnings

- Lane keeping assist *

- Curve assist *

- Rear view cameras

- Reversing proximity sensors

- Automatic parking *

- Blind Spot Detection

- Daytime running lights

- Cornering lights

- Auto-hold

This list may be divided into three functional groups.

1. Vehicle visibility enhancement for driver or nearby vehicles

2. Alerting the driver of potential threats to the vehicle

3. Automation. (*) Take control of the vehicle

In many cases technology starts out offering driver alerts and then evolves into a fully automated offering. For example, forward collision alerting evolves naturally into autonomous emergency braking. This appears to be a trend (which has both economic and technological components). As the technology in a warning system matures, a second generation of the technology emerges where these systems take control of the vehicle by braking, accelerating and even steering. In the extreme, we have Automatic parking where the driver engages the system and takes only small actions while the vehicle largely parks itself.

However it is worth consider that in mitigating particular risks, each of these technologies introduces new risks especially in how a driver interacts with the vehicle. Let us consider some of those in the light of currently available technologies.

Alert Based Systems

Many technologies are initially offered as alert based systems. In these systems an audible and/or visual alert is generated to inform the driver of a potential risk. Examples include Forward Collision Warnings, Lane Departure Warnings, and reversing proximity. While the technology might partially or even fully mitigate the targeted risk, the process of generating an alert and having the driver react to the alert introduces new risks.

Of particular concern with an alert based system is providing the alert in time for a driver to react and take appropriate action. To compensate for reaction time, an effective alert system needs to provide an alert that allows time for the driver to react to that alert. However, the earlier a prediction of a threat is made the more uncertain that prediction. Other events may occur to remove the potential threat. Many situations that look like a potential threat at a large time horizon resolve without incident. To the driver, any alert that does not resolve to a true threat will be perceived as a nuisance alert.

The manufacturer of the alert system has to decide whether to generate alerts for all situations deemed a potential risk at the necessary time horizon but with the strong likelihood it will result in

an increased occurrence of nuisance alerts, or do they reduce the time horizon to decrease the occurrence of nuisance alerts at the cost of a higher likelihood of negative outcomes—albeit with possibly reduced severity. Nuisance alerts pose an issue for the driver who has to determine their importance. They could be expected to be more casual in their response to the alert taking more time to take action, and potentially increasing the severity in the case of an alert before a crash. In systems that produce few nuisance alerts, the reverse situation is possible. A driver simply may not be exposed to the alert sufficiently to remember what it means or what action to take. So when a real alert occurs, the driver may not react in an appropriate way.

These concerns lead to the following questions:

- How affective is an alert / warning system?

- Do warning systems prompt a correct response from a driver?

- What is the effect of a significant number of nuisance alerts on driver behaviour to future alerts?

- How do drivers react to alerts that are infrequent and/or unfamiliar?

- What effect do multiple alert types have on a driver? How many alert types can a driver handle before becoming confused (cognitive/mental overload)?

A number of these issues have already been partly considered but the potential increase in warning systems may make this even more significant. For example, mental overload (Young & Lenné, 2013; Hancock & Parasuraman, 1992) may become an even more significant issue as a driver deals with alerts from multiple systems.

Automated Systems

Automated systems avoid a number of issues seen in alert based systems. With the vehicle taking action automatically, the driver is seemingly out of the loop. At first consideration it might seem unlikely that there are driver based risks. However, current automated systems either control the vehicle for a short period in response to a threat, or require the driver to manage and control the automated system itself. For example a driver sets the speed for cruise control. In systems that take control of a vehicle for a short period (such as Autonomous Emergency Braking or Lane Assist) the period of autonomous control can be timed in seconds. By briefly wresting control from the driver such systems clearly aim to mitigate against human error.

There are a number of risks posed by short period automation systems that are illustrated by the following questions:

- What are the limitations of the technology and do drivers understand those limitations? When might the technology fail to operate – especially when the driver is relying on it?

- Do drivers understand the technology?

- What are the effects of an intervention on the driver's ability to subsequently control the vehicle? For example, might they be shocked or scared by a "close call"?

- Is there a risk that a driver might come to rely on the technology? Could a driver become more aggressive thinking they will be saved by the technology?

- Might a driver of another vehicle act in a way that relies on the technology or take additional risks? For example, cut in on a vehicle with Autonomous Emergency Braking. (See Adell et. al., 2011; Young & Lenné, 2013)

- Could the technology hand control back to the driver (or the driver take control) when the vehicle is in a state that is difficult to handle—especially if the technology has been controlling the car close to the edge of its performance envelope?

Other automated systems such as adaptive cruise control and automatic parking perform tasks previously undertaken by the driver. These technologies appear as though they remove a task from the driver. However, these technologies ought to be viewed as tools requiring management and supervision as they control the vehicle. So rather than control the speed through use of accelerator and brake, the driver can control the speed through the use of the adaptive cruise control. In essence the driver is still in control.

One potential significant risk of automated systems is a loss of situational awareness. As the driver is now monitoring the control of some primary controls, a disconnection could occur between the driver and those primary controls. A slow degradation in conditions could go undetected by the driver because they do not have direct input into the control system. The adaptive cruise control and traction control systems could drive into these worsening conditions until a point is reached where the vehicle cannot be controlled in the conditions.

These kinds of issues pose some risks and another set of questions:

- How well do drivers understand the technology, especially in transition between handing over control and taking or receiving back control?

- Are there limitations to the technology and times when it might not work?

- Could the technology lead the vehicle into a dangerous situation without the driver becoming aware?

- Do drivers recognise the need to manage the vehicle and oversee the technology or do they "set and forget"? (See Totzke et al, 2011; Young & Stanton, 2007)

- Could the automated system hand control of the vehicle back to the driver in a state that is essentially uncontrollable?

Driver Resists Use

A new technology is of no use if a driver chooses not to use it or disables it. Anecdotal evidence suggests technology can be disabled due to drivers' frustration with that technology. Nuisance alerts and perceived false activations of technology seem a common reason and are possibly caused by differing driver risk profiles. It could also be caused by a failure of the design of the technology to consider other factors, such as different vehicle performance when ascending or descending a hill.

A number of issues present an impediment to the adoption of risk reducing technology and raise questions similar to earlier ones such as:

- What factors might cause a driver to disengage or fail to use a technology? What countermeasures are required?

- How well do drivers understand the technology? Do they require training or to be educated about the use case for the technology?

- How do driver's perceptions of risk differ between when they have control and when technology is enabled? Does evidence support or contradict those perceptions?

Future Technological Improvements and the Role of the Driver

It seems likely that a number of current technological improvements will be pushed further on the path to a fully automated vehicle. Lane assist and curve assist for example are likely to be refined to lane keeping and curve following. With these technologies once a vehicle is set up on a road, it may not require further input on the steering wheel for significant time and distance. Combined with adaptive cruise control, in some environments a vehicle would be capable of covering large distances and operating for a significant period of time without driver input.

Additionally a number of other new technologies are likely to reach vehicles in the next decade. Dedicated Short Range Communication (DSRC) allows vehicles to talk to each other, potentially providing information that is beyond the range of the driver's senses or the vehicle's sensors. These systems can provide alerts of potential collisions from all geometrical aspects. They can also warn of rapidly slowing traffic ahead. Communication with infrastructure can give drivers information on signal timing at an intersection, lane closures, and hazardous conditions. As communication systems mature, it is reasonable to expect alert systems to be replaced with automated actions. Vehicles might automatically brake to avoid collisions, or negotiate a mutually agreeable resolution with each other.

While the authors anticipate a longer time horizon to the fully automated vehicle than is often cited by technology evangelists, it is clear that the next decade will see significant automation introduced in production vehicles. This raises some significant questions regarding the role of the driver and new risks that this technology might introduce.

Driver's Role

There is a fundamental difference between today's automated technology and that likely in the future. Today's automated technology, such as adaptive cruise control, lane keeping assist and curve assist leave the driver in control. It is assumed that while using these technologies, the driver is managing and monitoring those systems to ensure they deliver the desired outcomes. The driver is not out of the loop but rather performing a modified role of managing technical systems that are driving the vehicle.

However, there is a strong risk that as vehicles become more automated, the role of the driver will become confused and poorly defined. As technology takes over the traditional role of acceleration, braking and steering, the driver's role in future vehicles will change from handling these primary controls to managing and monitoring systems that control those primary controls. Initially it would be expected that while no input by the driver will be required during normal operation in uneventful and controlled environments, the driver will continue to assess the environment for potential threats that may require manual intervention.

This poses a number of additional research questions:

- What role is a driver likely to play in a highly automated vehicle?

- If a driver's role becomes one of monitoring vehicle systems and reviewing the vehicle environment for threats, how good are they likely to be at this?[2]

- What training if any should a driver have to understand and manage an automated vehicle?

- Does this different driving method require licence endorsements?

- What level of attention should a driver pay to the performance of automated functions?

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[2] S Bainbridge (1987) indicates humans are not good at monitoring. Martens & van den Beukel (2013) discuss driver cognition being increased by monitoring an automated action.

- What level of attention should a driver pay to the outside environment?

- How should automated functions take over driving and pass control back to the driver?

- In a highly automated vehicle, can automated technology assume a driver is always available to take back control of the vehicle?

In considering the vehicle of the future, there are particularly interesting issues when a vehicle is in an environment where it can drive itself without the driver even monitoring the vehicle or environment. Further questions ought to be considered such as:

- If the vehicle can manage all environments, does the vehicle need a driver?

- Does the 'driver' need to be physically present in the vehicle or could a remote driver control the vehicle?

- What environment is required for safe operation? Can the technology handle pedestrians, broken down vehicles, cyclists, animals….

- Is it realistic to expect a driver to resume control when the environment is no longer appropriate or when a situation evolves that the vehicle's technology cannot handle? What kind of time notification to the driver should be required?

- Should regulators require a vehicle with such a technology to always be in a position where it can bring the vehicle to a complete stop in a safe environment?

Much of the talk in automated vehicle circles assumes that an automated vehicle would be able to "hand off" to the driver. Is this a realistic expectation? What are the potential risks raised by the assumption to be able to hand control back to the driver?

Perhaps the greatest risk is that market forces result in systems being deployed without proper consideration and research effort being given to these issues.

The fully connected automated vehicle

Again considering the vehicle of the future that is fully automated and able to handle many different types of environment. It is also connected to the road system. No longer is the vehicle an independent entity but a fully connected part of a distributed system. In this scenario a driver is not required in the vehicle. The road system is the driver and where manual intervention is required, it comes remotely or the vehicle is shut down and personnel are dispatched to the location.

Unlike today, the driver would no longer be a risk. So what are the risks? In this future environment, it will be users of other spaces close to the road system, or people who interact with the road system. It will be cyclists and pedestrians. It will be children in a park running after a ball onto the road. People will still make errors.

Changes and Impact on the Practice of Road Safety

Considering all that has been presented above, the ultimate question for the Road Safety community is: If the role of the driver changes, what will the new significant issues be and how might Road Safety change? As an example, it is worth noting that even today speeding could be rendered technically impossible in all new vehicles. That in itself would significantly change the face of Road Safety.

However, the most significant future changes are in the role of the driver. So what steps ought to be taken to mitigate the risks associated in the change of role of driver? Education surrounding the new technology, how it works, why it should (or even must) be used, how to use it, and its limitations

are all aspects that are currently lacking in the as new technology is introduced. There are areas that the Road Safety community should consider investigating.

Additionally there will be new areas to focus on. As drivers progressively present less risk in the road system, interaction of vehicles with pedestrians, cyclists and other road users are likely to become far more important.

Also while this paper has not addressed potential legal issues (and it is beyond the expertise of the authors), a number of issues are anticipated and these may be barriers to the introduction of technology with a significant safety benefit. For example, there are a number of areas where the driver is currently liable but where in the future technology makes this unreasonable. This area becomes particularly interesting when vehicles are acting based on trusted information from a third party. Potentially some significant work will need to be done in policy, regulation and law making.

Conclusions

Road safety has come a long way during the last several decades. Previous technological improvements have resulted in cars that are significantly more crashworthy than their predecessors. Road Safety practitioners have also focussed on the driver, a human who may err. Currently one of the greatest overall risks in the current road system is the driver.

Vehicle manufacturers are introducing a swathe of new technology designed to mitigate risks associated with common errors in human drivers. Autonomous Emergency Braking, Lane Assist and Curve Assist all seek to address situations where a driver has failed to take appropriate action to a risk.

Looking to the future, there is a wave of new technology descending on vehicles. This wave not only seeks to mitigate errors of human drivers but is likely to ultimately replace them. During this process, the role of the driver will change. This paper has sought to highlight those possible changes and provide questions for the Road Safety community to consider as it faces a wave of technology that will change the role of the driver and the whole road system. There is significant work to be done and the authors hope this paper helps Road Safety Practitioners consider the future of Road Safety.

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