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Why do we make safe behaviour so hard for drivers?

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Key Findings

- Stalled progress on improving road safety calls for new strategies.
- The Safe System approach tolerates road-user error so misses chances for prevention. .
- Many errors are caused by poor road system design as illustrated in this paper.
- More human-user centred road system design is needed to reduce errors and crashes.
- Poor design makes it hard for road-users to behave safely.

Abstract

Despite significant improvements in road safety in Australia and developed countries over some decades, the downward trend in fatalities and serious injuries has slowed markedly, and even stalled. New strategies are needed to turn this trend around. Current road safety philosophy, the Safe System, has been effective, but needs broadening to increase the scope of solutions. The Safe System accepts that road users make errors and that the road system should be forgiving of those errors. This leads to countermeasures that emphasise limiting consequences of crashes like lowered speeds, crashworthy vehicles and roads. The problem is that conceptualising road-user error as inevitable ignores the fact that many road-user errors are caused by poor design of the road system including roads, vehicles and road rules. It means road safety overlooks productive avenues for prevention of road-user error and crashes. This paper discusses this issue with Safe System and provides examples of poor road system design that make it difficult for road users to behave safely. This includes poor road rules like inappropriate speed limits, inadequate road design such as poor signage and confusing lane-marking, inadequate vehicle design that limits vision or provides false visual information, as well as problems with driver-assistive technologies: cruise control, automated driving and warning systems. In each case the paper discusses how poor design fails to account for human capacities making it hard for road-users to behave safely. Importantly the paper looks at solutions to these problems and provides some new principles for Safe System.

Keywords

Road-user error, Safe System, human factors and ergonomics, road safety strategy

Introduction

After decades of declining road fatality rates, we have become accustomed to expecting this to continue. In the last decade in Australia, and many similar developed countries, however, there has been a much slower rate of reduction in road-related deaths and almost none for serious injuries (Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2020). The WHO Global status report on road safety (2018), shows that this trend is occurring even in high-income countries which had previously shown years of improving road safety. In fact, in some years, these rates have increased. The lack of improvement means that the national road safety targets set for the 2011 to 2020 period in Australia for example, will not be met (Australian Automobile Association (AAA), 2019). These may have been ambitious targets, but currently road safety is making too little progress towards improvement. This has led to calls for new strategies to address road safety issues in Australia (AAA, 2019) and internationally (WHO, 2009; ITF, 2016). The problem is, what strategies and what issues?

The objective of this paper is to highlight a missing element in current road safety strategy: to design the road system to account for the capacities and limitations of road users. The current approach assumes that errors while driving are many, too difficult to change or cannot be avoided. This is based on an incorrect premise and a simplistic interpretation of the causes of crashes. Unfortunately, this also means that many of our current road safety practices are inadequate and the road system is unnecessarily difficult for road users. This paper puts forward evidence that driver error is not inevitable or irredeemable and in many cases is caused by inadequate design of aspects of the road system. This paper also shows how the current Safe System approach must be expanded to include strategies to reduce circumstances which make safe behaviour difficult for drivers. Failure to acknowledge these problems makes the road system less safe and worse means that we miss opportunities to improve safety.

Problems with the Safe System approach

In countries like Sweden, Netherlands and Australia, road safety strategy over the past decade or two has been based on the Safe System approach (OECD, 2008; ITF, 2016). Largely built on the concepts of Vision Zero (Tingvall and Haworth, 1999) and Sustainable Safety (Wegman et al., 2005), Safe System has become the basis for decision-making by road authorities and its influence can be seen in the sorts of strategies adopted (OECD, 2008; Australian Transport Council, 2011; ITF, 2016). The main principles of the Safe System are that humans will inevitably make errors and that there are known biological limits to the amount of force that can be tolerated before injury occurs. Under the Safe System approach the primary aim is to ensure a more forgiving road system such that forces in collisions do not exceed these limits and that mistakes by road-users do not result in harmful consequences like serious crashes and fatalities. This leads to the current approach which is to tolerate road user error but manage the consequences. This necessarily emphasises solutions that minimise damage to road users when a crash occurs such as seat belts, crashworthy vehicles, separated roads, crash barriers and limiting speeds. There is evidence of some degree of effectiveness in reducing road trauma for these strategies (Mooren, Grzebieta and Job, 2011; Weijermars & Wegman, 2011). But as seen in the crash statistics, there is clearly more work to do.

Safe System models of the road system include humans, but as disruptive influences due to inevitable errors and as a vulnerability due to the potential for injury due to biomechanical forces in crashes. They do not include an active role for the human-user in a safe road system. They largely overlook the strengths, capacities and limitations of humans and hardly consider how to design the system to be most usable for road-users. Most notably, both Safe System and Vision Zero assume that error is inevitable and do not consider the possibility of error prevention. The Dutch Sustainable Safety description of safe system incorporates prevention of human errors, especially through better design of roads that signal functionality and ensure homogeneity and predictability for users, but the inevitable fallibility of users is still recognised as a primary characteristic of this version of safe system. Where Safe System treats error as inevitable, the potentially important strategy of reducing road-user error is ignored or at least discounted. Worse, these approaches fail to recognise that some road safety practices actually create road user error. This means that our current Safe System approach is almost certainly missing out on opportunities to implement some potentially effective strategies to reduce driver error and is even advocating others that have negative effects on road safety.

Recently some have argued that road Safe System approaches should be expanded to encompass all components of the road system, including the impact of road safety legislation and policies, not just individual components, and also to broaden the focus to manage performance variability in the road system, rather than the narrower concept of human failure (Larsson, Dekker and Tingvall, 2010). Multiple studies by Salmon and colleagues have shown how Systems theory, borrowed from workplace safety, can reveal the complex network of interacting factors spanning multiple levels of the road transport system that precede crashes (eg., Salmon, Read, Stanton and Lenne, 2013; Salmon, Hulme, Walker, Waterson, Berber and Stanton, 2020). It is not yet entirely clear how this information can be used to predict accidents or prevent them (Grant, Salmon, Stevens et al, 2018). Further, while Systems theory acknowledges that road user error can be created by the road system, it has not taken it to the next step of encouraging solutions to prevent these errors.

The recent ITF/OECD 2016 report on a Safe System has taken a broader view of the role of the road-user in the road system than in the original 2008 report also by drawing on safe system ideas from sectors other than road safety (eg., Reason, 1997). This view acknowledges the role of multiple components in the road system and that many road-user errors arise from the interaction between the user and the complex components of the road system. It also recognises that the design and operation of a safe road transport system must consider the capacities and limitations of the human user. In spite of this, the first principle in this iteration of Safe System remains: that road users will inevitably make mistakes that lead to crashes. Unfortunately, this principle is not compatible with broader ideas of the Safe System approach. The recommended actions for road safety in this report still retain the focus on tolerating or accommodating for error and still point to human failure rather than designing for human capabilities, expectations and natural ways of behaving. It continues to emphasise the need to mitigate the consequences of error rather than prevent it.

This is most obvious in the advice provided on the design and operation of a safe system: ‘to guide and encourage safe behaviour by users when using the road transport network’ (ITF, 2016, pg 88). This approach assumes that the road system is perfect, and users need help to use it. This is in contrast to the approach from outside road safety which aims to design the system so that it is usable by users. The two approaches lead to different solutions. The ITF approach mainly calls for forgiving or crash mitigation solutions whereas solutions emphasising usability aim to minimise likelihood of error due to problems of use like perception difficulties, misunderstandings and confusions.

This paper puts a case for broadening the Safe System approach to recognise opportunities to prevent or reduce road-user error through improved design. It describes examples of failures of design in the road system that make road-user error more likely and that would not occur if usability was a primary focus in their design.

Is driver error the major cause of road crashes?

Road safety strategy is traditionally built on statistical evidence about road traffic crashes, particularly fatalities. This evidence highlights driver error as the predominant cause of crashes, with studies reporting that around 94% of crashes are caused by driver error (Treat, et al., 1979; Singh, 2015). Causes of crashes are mostly attributed to behaviours like inattention and distraction, speeding, perceptual errors and falling asleep (eg., Austroads, 2015). Unfortunately, most analyses of the causes of crashes are quite crude with emphasis on identifying and categorising a single cause of a crash and hardly ever at the interaction between factors contributing to the crash. Accident analysis in areas other than road safety have long recognised that accidents occur due to a combination of factors and events and almost never have a single cause (Feyer, Williamson and Cairns, 1997; Leveson, 2004). If only a single cause is identified, it is not surprising that it is the last event before the crash and, given the nature of driving, that it involves a failure in road-user behaviour. We almost never ask: Why did the road-user behave that way at that time? What other factors might have influenced the behaviour? This argument is supported in a recent paper by Hauer (2020). He critiqued the history of identifying road-users as the sole cause in crash causation studies on the basis that this impedes identification of targets for prevention that are broad enough to contribute to the Safe Systems approach.

The ITF (2016) report also called for more in-depth studies. It argued that these studies are needed to cover the different aspects of the road transport system in a search for root causes in the chain of events leading to crashes. This analysis should highlight avenues for prevention or mitigate similar crashes. Yet even recent in-depth crash studies (Wundersitz, Baldock and Raftery, 2014; Doecke, Thompson and Stokes, 2020) tend to report single causes along with a list of contributing factors to crashes rather than reflecting a network of causal elements. Even though very extensive, systems theory-based analyses of crashes (Salmon, et al., 2019) also miss out on linking specific types of behavioural failures to specific contributing factors. If only looking for a single causal factor, road safety is missing the opportunity to gain a deeper understanding of how crashes occur and to identify prevention opportunities through looking for common contributing factors across multiple crashes.

Building a better Safe System approach for road safety

Putting all this together, the current Safe System approach to road safety such as put forward in Australia and in the ITF report (2016) acknowledges road user error as the prime cause of crashes, supported by a narrow analysis of crash causes, but most of the solutions it advocates highlight minimising the *impact* of error-related crashes rather than preventing error occurring. In tolerating error, these interpretations of Safe System miss the fact that in a well-designed road system, most error need not occur. It ignores the fact that we often make the road system hard to negotiate for road users and that, as demonstrated by examples in this paper, many practices currently in place increase the risk of error rather than reduce it. The approach also ignores the capabilities of humans and the wealth of knowledge of the interaction between humans and the elements of the road system available from Ergonomics and Psychology (Oppenheim and Shinar, 2011; Woods, Dekker et al, 2012). We almost never acknowledge that road users often avoid crashes in poorly designed sections of the road system.

Of course, not all errors result directly from interactions with the immediate elements of the road system; for example, crashes involving drivers impaired by alcohol and drugs or fatigue. However, drivers affected by alcohol, drugs or fatigue are also less likely to cope with poorly designed elements of vehicles, roads and road rules. Good human-user centred design should mitigate crash risk for these factors as well by making the system easier to use even for impaired drivers.

Examples of problems in the road system for road users

There is a multitude of examples of poor design in the road system that make safe behaviour hard for drivers and road users and so increase the likelihood of error. Generally, these examples relate most directly to the problem for drivers, but they also have negative consequences for other road users such as pedestrians and cyclists as they are often involved in the crashes that result. This is important as around 50 percent of fatalities worldwide are vulnerable road users (WHO, 2019). This section describes some examples of road rules, road design and vehicle design that do not account for human capacities and so make it hard for drivers to behave safely and often increase crash risk for other road users as well. Why this is the case is explained and solutions to prevent errors occurring are suggested.

Road rules and enforcement

Speed management

Speed management is a primary component of both Safe System and Vision Zero approaches based on the relationship between speed and the forces generated in a crash where lowered speeds produce lower energy in a crash so reducing the physical trauma in crash outcomes (Elvik, 2012). Limiting speeds is a major feature of practices based on the Safe System (eg., OECD, 2008; ATC, 2011; ITF, 2016). Mostly the emphasis is on setting limits on speeds that are survivable if a crash occurs, obtaining compliance with speed limits through enforcement using monetary or point-based penalties and encouraging community acceptance of set speeds.

Unfortunately, there is considerable evidence that simply setting lower speed limits is a poor approach to safety as compliance often presents problems for drivers. Compliance is especially difficult when roads communicate conflicting information about appropriate speeds to drivers. To be effective, speed limits need to be creditable to drivers. Studies of rural roads in New Zealand (Charlton and Starkey, 2016), urban roads in Canada (Gargoum, El-Basyouny and Kim, 2016) and both road types in the UK (Yao, Carsten and Hibberd, 2020) show that road characteristics play a large role in compliance with speed limits. Road conditions that signal the potential to do higher speeds than posted such as wide or multilane roads or where the limit is higher than drivers prefer such as roads containing hazards like parked cars, pedestrians or cyclists both create problems for drivers and reduce compliance. A US study also showed that discrepancies between recommended speed limits based on engineering review and the posted speed limit also reduce compliance with the posted limits (Gayah, Donnell, Yu and Li, 2018). As posted speed and engineering recommended speed become more consistent, so does the level of compliance with speed limits. Drivers respond to plausible or creditable factors when choosing their speed, not necessarily the posted speed.

Compliance is also affected when drivers fail to notice speed limit changes. Placement and style of speed signs is obviously important (Wallis and Bulthoff, 2000). Yet Harms and Brookhuis (2016) showed that despite driving a familiar route, drivers did not notice even prominently placed and repeated presentations of altered speed limits. The authors concluded that this failure was related to habituation to aspects of the driving task and not deliberate ignoring of speed signs, as drivers showed no evidence of attention loss in two other imposed tasks during the drive.

Approaches to encourage compliance are mostly linked to enforcement by police through financial or point-based penalties. Evidence shows that police enforcement produces lower and compliant speeds (Gayah et al, 2018) and even presence of police cars lowers speeds (Charlton and Starkey, 2016). Nevertheless, enforcement of speed limits is not entirely supported by the driving community. Surveys consistently show that a significant percentage of drivers view speed enforcement as revenue raising rather than making roads safer (eg., TAC, 2018; Mooren et al., 2013).

A focus mainly on reducing speed limits will always struggle to achieve compliance without significant effort to enforce vigorously although some newer approaches to speed management such as point-to-point speed cameras show promise in increasing compliance and reducing speeding and crashes (Soole et al., 2013). On the other hand, there is considerable research showing that lowered speeds can be produced with little or no enforcement if the speed limits are credible. The concept of self-explaining roads aims to provide this credibility though road layout and environment design (Theeuwes and Godthelp, 1995). This is a central element in the Dutch Sustainable Safety approach (Wegman, Dijkstra, Schermers, and van Vliet, 2005) which emphasises that speed limits must be consistent with road design and the environment to be functional, predictable for drivers and forgiving when crashes occur. This approach has been shown to be effective in reducing crashes in the Netherlands (Weijermars and Wegman, 2011) and reducing speeds in New Zealand (Charlton et al., 2010).

The credibility concept has been included in the road safety strategies of other countries like Australia, although in practice, the primary focus is strongly on setting lower speed limits. For example, the Australian government 2018 inquiry into road safety (Woolley and Crozier, 2018) recommended lowering urban speed limits to 30km/h and included using speed moderating installations where appropriate. A recent joint proposal to the Australian Government by peak road and public safety organisations argues for implementation of temporary speed limit reductions to 30km/h during the COVID-19 pandemic (Lea, Fogarty et al., 2020) with no mention of associated traffic calming treatments.

In summary, the problems for drivers in managing speed suggests that speed limits must be compatible with the characteristics of the road system and be credible. Road safety problems should not be solved by only reducing speed limits but must be accompanied by modifications to the road system such as traffic calming and self-explaining roads. These signal to drivers that a slower speed is needed and, even better, encourages them to do so as they naturally drive at lower speeds and do not require constant checking of speedometer. Slower speeds also have significant benefits for reducing crashes for vulnerable road users (Hussain et al., 2019).

Figure 1: Example of poor and confusing signage

Poor or inadequate road design

Confusing road signs

Signage that is too complex for a driver to understand in the short period available to process and react to its content will make safe behaviour very difficult for drivers (Ben-Bassat & Shinar, 2006). The problem is worse if the signage contains information about recent changes to the road system. Figure 1 shows an example of the problem of inadequate signage on a multilane arterial road in Sydney which failed to provide adequate direction to drivers about a change to a major interchange. Since late 1992, access to the M4 motorway westbound from Homebush Bay Drive was via a right-hand turn at traffic lights. In early 2017, after the widening of the M4, a new interchange introduced a G loop lead-on to the M4, but was now accessed from the left-hand lane of Homebush Bay Drive, almost opposite the previous right hand turn. The change was publicised through the media, but the only on-road warning of this change was the very complex sign shown in Figure 1 which was also placed very close to the exit. This sign also contains information about the new access, also by left-hand exit to the same M4 motorway, but eastbound. With the speed limit of 80kph in this section, there is little time for drivers to process this information as they pass the sign at around 22 metres per second. Even worse, drivers who, for more than 20 years, had accessed the M4 westbound using the right-lane, suddenly had to make three, very rapid and unsafe lane changes to access the correct left-lane, or overshoot the turn and then work out how to correct the problem. Drivers who attempt to correct course rather than miss the turnoff would be judged to be unsafe, negligent or even reckless rather than responding to a poorly designed section of road.

Within months of the opening of the M4 access, temporary bollards, then concrete barriers were erected to prevent drivers from making these risky lane-changes. The need to retrofit bollards and barriers is evidence of poor design and management of this change to the road system. A simple, low-cost solution would have informed drivers of the need to prepare for this change by providing more signage along the three to four kilometres of largely uncluttered road leading to the new M4 turnoff.

Guidance on road signage is very well-advanced and regularly updated. For example, the Australian Guide on traffic management devices (Austroads, 2020) calls for signs to be an adequate size and properly located so that drivers can read and act on the message, not be too complex in design and provide adequate warning of hazards or decision points. It also states that ‘Signs or markings can seldom be used to solve problems caused by poor and confusing road geometry’. Given this acknowledgment by road safety authorities of the need for good design of road signage and markings, it is puzzling that such poor design is tolerated on our roadways. Even worse, that drivers’ attempts to overcome poor signage are judged as driver risk-taking or error if these attempts have adverse safety consequences.

Confusing lane markings

There are multiple other examples of poor road design that confuse or make it difficult for drivers to behave safely. An example is displayed in Figure 2 where normal white lane markings have been overlaid by temporary yellow lane markings because of the demands of road construction or maintenance. Yellow lines are added as a less costly option to resealing the road (IPWEA, 2012). The problem exists where older, white markings are left in place and

Source: Wayne Taylor, Herald Sun, 13 September, 2017

Figure 2: Example of confusing lane markings

newer yellow markings are added. Despite signage to direct drivers to follow the yellow lines, the situation can be very confusing to drivers especially where they miss noticing the sign. This increases the changes that drivers inadvertently follow the wrong lane markings, causing unnecessary uncertainty and misunderstanding between drivers. Again, this should not be judged as a driver error, rather it occurs as a result of poor lane marking on roads. The solution is clearly to avoid confusing lane markings.

High visual clutter and complexity in driving environments

The driving environment is often highly complex as shown in the example in Figure 3. Areas of competing road activities such as the one shown, with moving cars, parked cars, trams, bicycle lanes and pedestrians are very common in our urban road systems. There is evidence of increased crash risk on roads with on-street parking compared to similar roads without it (Griebe, 2003) and of behavioural change by drivers in more complex road environments (Edquist, Rudin-Brown and Lenne, 2012). Drivers compensated for the more challenging road environment by slowing speed and moving closer to the centre of the lane, but this was not sufficient to avoid increased crash risk. Other studies also showed that complex road environments increase cognitive demand on drivers and require considerably more attentional resources (eg., Pratten et al., 2004; Stinchcombe and Gagnon, 2010).

In environments such as shown in Figure 3, therefore, the potential is very high for drivers to miss out on important elements such as a pedestrian or cyclist wearing dark clothing, or a lower speed zone sign. In these driving environments where drivers are expected to pick out specific or important information, driver behaviour will often not be perfect and consequently may not be safe. It will certainly also have adverse consequences for vulnerable road users. Again, this failure should not be attributed to driver error, rather it is a consequence of inadequate design of the road system. A primary solution to this problem is to avoid road environments like this through separation of road uses such as only allowing off-street parking, separating all types of vehicles by separating car, tram and bicycle lanes and separating pedestrian traffic.

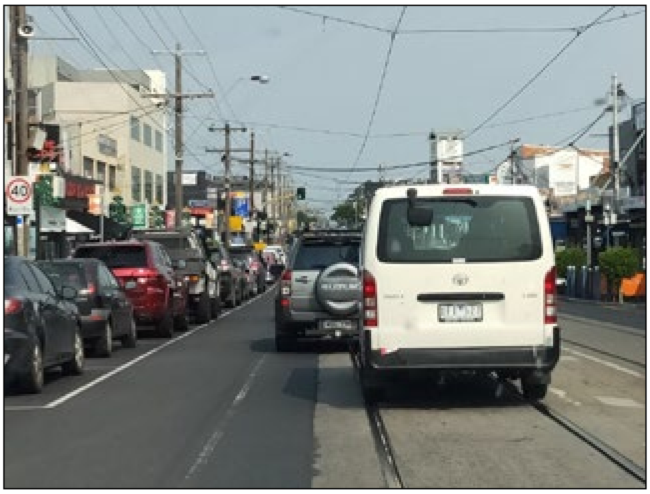

Figure 3: Example of high visual clutter and complexity in the road environment

Figure 4: Example of poor visibility from vehicles showing pedestrian standing close to the vehicle is completely obscured by the A pillar

These three examples show that even when the foundations of good, safe, human-user centred road design are available in principle, such as for signage, they often do not appear in use. If the prevailing road safety philosophy assumes that driver and road user errors are inevitable, it is perhaps not surprising that this situation is allowed to persist with little attempt to prevent errors.

Problems of vehicle design

Vision from vehicles

Modern car design is applauded as one of the contributors to a safer road system. Certainly, improved crashworthiness of vehicles has helped to reduce the severity of crashes and likelihood of fatalities (Glassbrenner, 2012). On the other hand, some aspects of vehicle design, especially those relating to the driving task have not improved and some have even become poorer. Visibility from vehicles is a good example. Being able to see the road to the front and side are primary prerequisites for drivers to safely negotiate the road system. Even so, the view from the driver seat is often occluded to the front and side of the vehicle by wider A-pillars designed to accommodate airbags and to increase roof strength and to the front by higher and more crashworthy vehicle fronts for vehicles with shorter front crumple zones such as vans or people movers. The problem is that these design features can restrict driver vision of important road features such as pedestrians, cyclists and road signs (see Figure 4). This effect is most pronounced in larger vehicles such as trucks (Kim, Ulfarsson, Shankar et al, 2010) and emergency vehicles (Hsaio, Change, Simeonov, 2014). An analysis of

From driver perspective

Actual distance

Figure 5: Example of the false visual information from convex side mirrors

fatal crashes involving pedestrians and trucks in the USA (Retting, 1993), for example, highlighted the problem of increased pedestrian safety risk due to poor visibility from trucks and called for better design of truck cabs to enhance the drivers forward field of view. Despite this, there has been little change in truck design since then. A search of the literature could locate no studies of the influence of poor vision from smaller vehicles like cars on crash risk despite obvious problems of vision in car design as shown in Figure 4. Ignoring this potential problem means poor vision from vehicles is highly unlikely to be acknowledged as a reason for drivers failing to see and respond to pedestrians so will not be solved, again increasing pedestrian injury risk. The problem is unlikely to be solved until its evidence is acknowledged.

Side mirrors

Another example of vision problems in vehicles is the design of sidemirrors. Many vehicles now have convex mirrors on the passenger and driver side of the vehicle. These mirrors are promoted as safety features that reduce the blind spot to vehicles approaching from the rear in the adjacent lane by providing a wider field of view. The problem is that the convexity of the mirror also gives false information about the distance from the vehicle coming up behind in the adjacent lane as they appear smaller than they actually are. This means that drivers will overestimate the time they have to safely move into the overtaking or adjacent lane and so increase the risk of crashes. Drivers appear to be able to adapt to this false information as they become more experienced with it (Hahnel and Hecht, 2012), but are unlikely to do so in circumstances of haste, stress or fatigue when safety risk for overtaking and lane changing will be high. Despite this evidence, there has been no analysis of the role of convex mirrors in these types of crashes, and again, this would just be attributed to driver error. The problem of convex sidemirrors has been acknowledged in Australia (eg., RACV, 2016) and there is debate around the world on whether convex mirrors should be used in vehicles. Yet they are still included as standard in many vehicles and are permitted in Europe, sometimes with a warning on the mirror that ‘Objects in mirror are closer than they appear’, a solution unlikely to be effective. Why do we include features in vehicles that make safe behaviour harder for drivers and increase crash risk?

Technology in vehicles

New technologies are being added to vehicles on the premise that they assist or even replace drivers and so prevent driver error. Unfortunately, the claims of benefits for many technologies are only partially supported by research evidence. There are many examples, some emerging in prototype vehicles and others already in standard vehicles.

For example, Visibility Enhancement Systems (VES) are promoted as positive safety features as they selectively enhance features of the roadway to drivers especially under conditions of low visibility. Evaluation of these systems shows that when using VES, drivers reported greater confidence and less stress but, contrary to conventional wisdom, reaction time to objects is slowed and collisions increased (Sharfi and Shinar, 2014). As these authors point out, the safety benefits of new technologies cannot be assumed and that they must be evaluated before being used on-road.

Another example is cruise control and adaptive cruise control. These technologies have been standard in vehicles for some years. Yet multiple studies show consistently that cruise control and adaptive cruise control significantly slow driver reaction times in emergency situations when drivers are required to take-over, and speedy responses are most needed (eg., Vollrath, Schleicher and Gelau, 2011; Pauwelussen and Feenstra, 2010; Piccinini Rodrigues et al., 2014; Jammes, Behr et al, 2017). These findings of increased crash risk when drivers return to manual control of speed, are rarely acknowledged by road safety authorities and drivers are not educated on this adverse side-effect of using this technology. Experience using cruise control reduces the higher crash risk (Larsson, Kircher and Hultgren, 2014), but it takes around 400km of driving experience to know and understand adaptive cruise control (Hynd et al., 2015). This means that even if drivers do get used to this technology, there is a significant period of higher safety risk involving slow responses to unexpected events and we do not know how drivers cope with this technology in times of pressure.

This problem is even more pronounced with newer automated driving technologies that partially or fully take over control of aspects of the driving task. Growing evidence on transitions from autonomous to manual driving control when automation requests it or where it fails, indicates a period of high safety risk. Multiple studies show that drivers need at least two to five seconds to regain initial control (see Vogelpohl, Kuhn et al, 2018 for review) and that stable control only returns 35 to 40 seconds after disengagement (Merat, Jamson, Lai et al, 2014). Even in takeovers that were not time-critical, takeover time was not affected but the quality of driving deteriorated in terms of poorer lane-keeping performance (Zeeb, Buchner and Schrauf, 2016). In the time to transfer control the vehicle can cover significant distances and many events can be missed. Again, these failures should not be regarded as driver errors as they occur due to poor design and implementation of a supposedly assistive technology. Transition of vehicle control is a major concern for automation that must be addressed before automated technology is allowed in vehicles on-road.

Many in-vehicle technologies operate by auditory warnings to drivers of a hazard while driving, including front and rear obstacles, blind spot, lane departure or speeding. While it might be assumed that drivers would benefit from

Table 1. Principles of the Safe System philosophy used in the National Road Safety Strategy 2011-2020 and the proposed Expanded principles of Safe System philosophy to include human-user-centric values.

	Current Australian Safe System principles (National Road Safety Strategy 2011-2020)	**ITF/OECD Safe System guiding principles (2016)**	**Expanded Safe System principles to include human-user centric values**
Objective	The transport system should not result in death or serious injury as a consequence of errors on the roads.	The design and operation of the road transport system should guide the road user to safe behaviour and mitigate the consequences of common human errors.	The transport system should not result in death or serious injury on the roads.
Principle 1	**People make mistakes.** Humans will continue to make mistakes, and the transport system must accommodate these.	**People make mistakes** that can lead to road crashes.	**A Safe System is designed to be easy for humans to use**. People make mistakes for many reasons. In designing roads, environments, vehicles and road rules, we need to design for human capabilities and limitations to avoid increased likelihood of road-user error.
Principle 2	**Human physical frailty.** There are known physical limits to the amount of force our bodies can take before we are injured.	**The human body has a limited physical ability to tolerate crash forces** before harm occurs.	**Human physical frailty.** There are known physical limits to the amount of force our bodies can take before we are injured.
Principle 3	**A 'forgiving' road transport system.** A Safe System ensures that the forces in collisions do not exceed the limits of human tolerance. Speeds must be managed so that humans are not exposed to impact forces beyond their physical tolerance. System designers and operators need to take into account the limits of the human body in designing and maintaining roads, vehicles and speeds.	**A shared responsibility** exists amongst those who design, build, manage and use roads and vehicles and provide post-crash care to prevent crashes resulting in serious injury or death	**A shared responsibility** exists amongst those who design, build, manage and use roads and vehicles to prevent road-user errors where possible and provide post-crash care to prevent crashes resulting in serious injury or death
Principle 4		All parts of the system must be strengthened to multiply their effects; and if one part fails road users are still protected.	**Encourage resilience of system solutions so if one part fails, road users are still protected.**

extra inputs about hazards, the sensors often lack precision with many false alarms, are redundant as they do not provide new information to the driver and just increase driver irritation (eg., Varhelyi, Kaufmann and Persson, 2015). Given a choice, many drivers would not continue to use them (Thompson, MacKenzie et al., 2018) as shown from survey of drivers who had trialed Intelligent Speed Adaptation technology.

The common problem with new technologies is that they are assumed to be assistive and safer and are introduced into vehicles on that basis alone. Evaluation of effectiveness focusses only on demonstrating that the technology works as intended and does not include how drivers interact with it in use. Drivers often report finding these technologies useful and use them willingly but may not be aware of their limitations. Despite good evidence of poor design or implementation, such as take-over problems for cruise control and autonomous control, little or no attempts are made to correct them and their potential role in causing crashes is either ignored or attributed to driver error. It seems that we are far more prepared to attribute crashes where a driver misses a pedestrian due to a large "A" pillar or overtakes into the path of a vehicle in the next lane due to the false information provided by their convex side mirror, as a fault of the driver not looking carefully or risky driving, rather than acknowledging that design of the vehicle makes it extremely difficult if not impossible to obtain the information drivers need to be safe. To improve safety on our roads, vehicle design including all new technologies must become more driver and road-user focussed.

An expanded version of Safe System for road safety

This paper describes a few examples of poor road system design that make safe behaviour difficult for drivers and increase the likelihood of crashes involving them and often vulnerable road users as well. If we are serious about road safety, we cannot continue to ignore these problems and must take active steps to solve them. A first step must be to amend the concept of Safe System for road safety and expand it to include prevention of road-user error through better human-user centred system design. Table 1 contrasts the current safe system philosophy used in Australia and that included in the most recent ITF/OECD report (2016) and proposes amendments to become more human-user centric. Note that the primary proposed change is to the first principle of the Safe System philosophy advocated by both OECD and Australia; that errors are inevitable. The proposed approach instead calls for this principle to encourage better usability of the road system through action to prevent road-user errors caused by poor system design.

Like the other two approaches, the proposal retains the second principle that acknowledges the physical frailty of human-users of the road system. The third principle in both Australian and ITF approaches emphasises crash mitigation that limits the level of injury to road-users, but the ITF also accentuates the shared responsibility of all road system partners in doing so. The proposed approach builds on the ITF version by incorporating shared responsibilities but expands it again by calling for the responsibility to extend to prevention of road-user error as well. Unlike the Australian version, the ITF also included a fourth principle that relates to creation of resilience in the road system such that if one element of the system fails, others will protect. This calls up concepts of resilience which have been used to describe the maintenance of safety in general (eg., Woods et al.,2012) and in the road system (eg., Van der Horst, 2012) through ensuring that failures of one part of the system do not result in crashes. To reflect this broader foundation, the proposed fourth principle includes this concept.

Conclusions

We need to expand the focus of road safety to take account of the needs of road users. There is little point in implementing poorly designed elements of the road system and simply calling it error when road users are unable to compensate for it. We should not be implementing strategies and practices that make safe behaviour more difficult for road users. Rather than road user error being inevitable and to be forgiven through making vehicles and infrastructure more crashworthy, focus needs change to include reduction or prevention of error in the first place in addition to minimising the effects of errors if they cannot be prevented. There are multiple examples of poor road system elements that make it difficult for road users to behave safely and, with the advent of new technologies in vehicles, this is becoming more evident. We are ignoring evidence that many strategies and practices in use, even those based on the Safe System approach, create problems for users and reduce the likelihood of improving safety.

The traditional targets for improving road safety of engineering, education and enforcement are necessary strategies to improved road safety, but they are not sufficient. These alone will not address the problem of crashes for road safety because they are not adequately addressing road user behaviour. Engineering approaches to roads and vehicles must incorporate good human-user centred design. This means implementing good ergonomic design that considers human information processing principles and stereotypes in the way humans behave naturally and expect the world around them to behave. While education is essential to ensure that road users are aware of important attributes of their road system, it should not be expected to be enough to produce changed behaviour. Similarly, rules and enforcement can be effective for behaviour change but if handled poorly have unintended consequences. Rather than changing behaviour permanently, it can produce only temporary compliance and lack support from road-users, resulting in an endless spiral of ever-increasing penalties. Better approaches are to make the targeted behaviour consistent with the preferred, natural response of drivers, such as limiting speed on self-explaining roads and encouraging driver perceptions of the risk of not doing so.

Humans can learn and adapt or compensate for poor design in the road system. This is almost certainly why we don't have more crashes, but in all of these examples where the road system is not designed to accommodate human behaviour, the risks that road-users do not cope with the challenging conditions increases, behaviour becomes less safe and crashes more likely. The point in this paper is not that the Safe System approach is contributing to failures, but that the approach is missing opportunities to reduce road user errors where they occur due to elements in the system that do not acknowledge the human user. Not all road user errors occur due to poor usability (eg., factors like driver impairment) but a substantial proportion do. Making the road system more usable will enhance safe system by making user errors far less likely. We are missing an enormous opportunity to improve road safety by ignoring the interaction of the human road user elements in the system with other parts of the system. At a time when we are making too little progress in reducing the number of people killed and seriously injured on our roads, this is an opportunity to do better.

References

Australian Automobile Association (AAA). (2019). *Benchmarking the performance of the National Road Safety Strategy*. Retrieved from http://www.aaa.asn.au/storage/benchmarking-the-performance-of-the-national-road-safety-strategy-june-2017.pdf

Australian Transport Council. (2011). National road safety strategy 2011-2020. *National Road Safety Strategy*, 1–67. Retrieved from https://www.roadsafety.gov.au/sites/default/files/2019-11/nrss_2011_2020.pdf

Austroads. (2020). *Guide to Traffic Management Part 10: Transport Control – Types of Devices, Edition 3.*

Ben-Bassat, T., & Shinar, D. (2006). Ergonomic Guidelines for Traffic Sign Design Increase Sign Comprehension. *Human Factors*, *48*(1), 182–195. https://doi.org/10.1518/001872006776412298

Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2020, Road trauma Australia 2019 statistical summary, BITRE, Canberra ACT.

Charlton, S. G.; Mackie, H. W.; Baas, P. H.; Hay, K.; Menezes, M.; Dixon, C., (2010). Using endemic road features to create self-explaining roads and reduce vehicle speeds, *Accident Analysis & Prevention,* 42(6), 1989–1998.

Charlton, S. G., & Starkey, N. J. (2016). Risk in our midst: Centrelines, perceived risk, and speed choice. *Accident Analysis and Prevention*, *95*, 192–201. https://doi.org/10.1016/j.aap.2016.07.019

Doecke, S., Thompson, J., & Stokes, C. (2020). How do we prevent and mitigate crashes? Evidence from Australian at-scene in-depth crash investigations. *Journal of Road Safety*, *31*(2), 35–43. https://doi.org/10.33492/jrs-d-19-00254

Edquist, J., Rudin-Brown, C. M., & Lenné, M. G. (2012). The effects of on-street parking and road environment visual complexity on travel speed and reaction time. *Accident Analysis and Prevention*, *45*, 759–765. https://doi.org/10.1016/j.aap.2011.10.001

Elvik, R. (2012). Speed Limits, Enforcement, and Health Consequences. *Annual Review of Public Health*, *33*(1), 225–238. https://doi.org/10.1146/annurev-publhealth-031811-124634

Feyer, AM., Williamson, A., Cairns, D. (1997). The involvement of human behaviour in occupational accidents: Errors in context. *Safety Science*, *25*, 55–65. https://doi.org/doi.org/10.1016/S0925-7535(97)00008-8

Gargoum, S. A., El-Basyouny, K., & Kim, A. (2016). Towards setting credible speed limits: Identifying factors that affect driver compliance on urban roads. *Accident Analysis and Prevention*, *95*, 138–148. https://doi.org/10.1016/j.aap.2016.07.001

Gayah, V. V., Donnell, E. T., Yu, Z., & Li, L. (2018). Safety and operational impacts of setting speed limits below engineering recommendations. *Accident Analysis and Prevention*, *121*(August), 43–52. https://doi.org/10.1016/j.aap.2018.08.029

Glassbrenner D. (2012). *An Analysis of Recent Improvements to Vehicle Safety, DOT HS 811 572*. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811572

Grant, E., Salmon, P. M., Stevens, N. J., Goode, N., & Read, G. J. (2018). Back to the future: What do accident causation models tell us about accident prediction? *Safety Science*, *104*(April 2017), 99–109. https://doi.org/10.1016/j.ssci.2017.12.018

Greibe, P. (2003). Accident prediction models for urban roads. *Accident Analysis and Prevention*, *35*, 273–285. https://doi.org/10.1016/S0001-4575(02)00005-2

Hahnel, U. J. J., & Hecht, H. (2012). The impact of rear-view mirror distance and curvature on judgements relevant to road safety. *Ergonomics*, *55*(1), 23–36. https://doi.org/10.1080/00140139.2011.638402

Harms, I. M., & Brookhuis, K. A. (2016). Dynamic traffic management on a familiar road: Failing to detect changes in variable speed limits. *Transportation Research Part F: Traffic Psychology and Behaviour*, *38*, 37–46. https://doi.org/10.1016/j.trf.2016.01.005

Hsiao, H., Chang, J., & Simeonov, P. (2018). Preventing Emergency Vehicle Crashes: Status and Challenges of Human Factors Issues. *Human Factors*, *60*(7), 1048–1072. https://doi.org/10.1177/0018720818786132

Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., & Olivier, J., (2019). The relatnionship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis. *Accident Analysis and Prevention*, 129, 241-249.

Hynd, D., McCarthy, M., Carroll, J., Seidl, M., Edwards, M., Visvikis, C., Tress, M., Reed, N., and Stevens, A., TRL. (2015). *Benefit and Feasibility of a Range of New Technologies and Unregulated Measures in the fields of Vehicle Occupant Safety and Protection of Vulnerable Road Users. EU Final report. European Commission*. Retrieved from https://doi.org/10.2769/497485

IPWEA. (2012). Victorian trial to distinguish lane markings in road-work zones. Retrieved from https://www.ipwea.org/blogs/pwpro/2012/11/07/victorian-trial-to-distinguish-lane-markings-in-road-work-zones

ITF (2016), *Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System*, OECD, Publishing, Paris. *http://dx.doi.org/10.1787/9789282108055-en* Jammes, Y., Behr, M., Llari, M., Bonicel, S., Weber, J. P., & Berdah, S. (2017). Emergency braking is affected by the use of cruise control. *Traffic Injury Prevention*, *18*(6), 636–641. https://doi.org/10.1080/15389588.2016.1274978

Kim, J. K., Ulfarssom, G. F., Shankar, V. N., & Mannering, F. L. (2010). A note on modeling pedestrian-injury severity in motor-vehicle crashes with the mixed logit model. *Accident Analysis and Prevention*, *42*(6), 1751–1758. https://doi.org/10.1016/j.aap.2010.04.016

Larsson, A. F. L., Kircher, K., & Hultgren, J. A. (2014). Learning from experience: Familiarity with ACC and responding to a cut-in situation in automated driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *27*(PB), 229–237. https://doi.org/10.1016/j.trf.2014.05.008

Larsson, P., Dekker, S. W. A., & Tingvall, C. (2010). The need for a systems theory approach to road safety. *Safety Science*, *48*(9), 1167–1174. https://doi.org/10.1016/j.ssci.2009.10.006

Lea, T., Fogarty, N., et al. (2020). *COVID-19 response proposal : reduce trauma by temporary urban speed limit reduction*. https://acrs.org.au/wp-content/uploads/2020/04/COVID-19-Temporary-Urban-Speed-Limit-Reduction.pdf

Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, *42*(4), 237–270. https://doi.org/10.1016/S0925-7535(03)00047-X

Merat, N., Jamson, A. H., Lai, F. C. H., Daly, M., & Carsten, O. M. J. (2014). Transition to manual: Driver behaviour when resuming control from a highly automated vehicle. *Transportation Research Part F: Traffic Psychology and Behaviour*, *27*(PB), 274–282. https://doi.org/10.1016/j.trf.2014.09.005

Mooren, L., Grzebieta, RH., Job, S. (2011). Safe system: comparisons of this approach in Australia. In *Australasian College of Road Safety Conference, 2011. Melbourne, Australia* (pp. 1–16). https://acrs.org.au/wp-content/uploads/Mooren-et-al-Safe-System-%E2%80%93-Comparisons-of-this-Approach-in-Australia.pdf

Mooren, L. Grzebieta, R. & Job, S. (2013). Speed - the biggest and most contested road killer. In *Australasian College of Road Safety Conference, 2013. Melbourne, Australia*. https://acrs.org.au/article/speed-the-biggest-and-most-contested-road-killer/

OECD. (2008). *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach*. Retrieved from https://www.oecd-ilibrary.org/transport/towards-zero_9789282101964-en

Oppenheim, I., & Shinar, D. (2011). *Human factors and ergonomics*. *Handbook of Traffic Psychology*. Elsevier. https://doi.org/10.1016/B978-0-12-381984-0.10015-3

Patten, C. J. D., Kircher, A., Östlund, J., Nilsson, L., & Svenson, O. (2006). Driver experience and cognitive workload in different traffic environments. *Accident Analysis and Prevention*, *38*(5), 887–894. https://doi.org/10.1016/j.aap.2006.02.014

Pauwelussen, J., & Feenstra, P. J. (2010). Driver behavior analysis during ACC activation and deactivation in a real traffic environment. *IEEE Transactions on Intelligent Transportation Systems*, *11*(2), 329–338. https://doi.org/10.1109/TITS.2010.2043099

Piccinini, GFB., Rodrigues, C., & Leitão, M., Simões, A. (2015). Reaction to a critical situation during driving with Adaptive Cruise Control for users and non-users of the system. *Safety Science*, *72*, 116–126. https://doi.org/10.1016/j.ssci.2014.09.008

Retting, R. A. (1993). A study of fatal crashes involving pedestrians and trucks in four cities. *Journal of Safety Research*, *24*(4), 195–203. https://doi.org/10.1016/0022-4375(93)80001-R

Royal Automobile Club of Victoria. (2016). Convex mirrors don't belong on new cars. Retrieved from https://www.racv.com.au/membership/member-benefits/royalauto/archive/convex-mirrors-dont-belong-on-new-cars.html

Salmon, P. M., Hulme, A., Walker, G. H., Waterson, P., Berber, E., & Stanton, N. A. (2020). The big picture on accident causation: A review, synthesis and meta-analysis of AcciMap studies. *Safety Science*, *126*(February), 104650. https://doi.org/10.1016/j.ssci.2020.104650

Salmon, P. M., Read, G. J. M., Beanland, V., Thompson, J., Filtness, A. J., Hulme, A., … Johnston, I. (2019). Bad behaviour or societal failure? Perceptions of the factors contributing to drivers' engagement in the fatal five driving behaviours. *Applied Ergonomics*, *74*(April 2018), 162–171. https://doi.org/10.1016/j.apergo.2018.08.008

Salmon, P. M., Read, G. J. M., Stanton, N. A., & Lenné, M. G. (2013). The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings. *Accident Analysis and Prevention*, *50*, 1278–1288. https://doi.org/10.1016/j.aap.2012.09.029

Sharfi, T., & Shinar, D. (2014). Enhancement of road delineation can reduce safety. *Journal of Safety Research*, *49*(February), 61.e1-68. https://doi.org/10.1016/j.jsr.2014.02.011

Singh, S. (2015). *Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey, Washington DC: NHTSA:Report No DOT HS 812. National Highway Traffic Safety Administration*. Washington DC. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812506

Soole, D.W.; Watson, B.C.; Fleiter, J.J. (2013). Effects of average speed enforcement on speed compliance and crashes: A review of the literature, Accident Analysis and Prevention, 54, 46-56. https://doi.org/10.1016/j.aap.2013.01.018

Stinchcombe, A., & Gagnon, S. (2010). Driving in dangerous territory: Complexity and road-characteristics influence attentional demand. *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(6), 388–396. https://doi.org/10.1016/j.trf.2010.06.008

Theeuwes, J., & Godthelp, H. (1995). Self-explaining roads. *Safety Science*, *19*(2–3), 217–225. https://doi.org/10.1016/0925-7535(94)00022-U

Thompson, J. P., Mackenzie, J. R. R., Dutschke, J. K., Baldock, M. R. J., Raftery, S. J., & Wall, J. (2018). A trial of retrofitted advisory collision avoidance technology in government fleet vehicles. *Accident Analysis and Prevention*, *115*(March), 34–40. https://doi.org/10.1016/j.aap.2018.02.026

Tingvall, C., Haworth, N. (1999). Vision Zero - An ethical approach to safety and mobility. In *6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne,*. Retrieved from https://www.monash.edu/muarc/archive/our-publications/papers/visionzero

Transport Accident Commission (TAC). (2018). *Road Safety Monitor 2018*. https://www.tac.vic.gov.au/__data/assets/pdf_file/0018/417420/Road-Safety-Monitor-2018-Final-Report-23.01.20.pdf

Treat, JR., Tumbas, NS., McDonald, ST., Shinar, D. et al. (1979). *Tri-level Study of the Causes of Traffic Accidents*. *Department of Transportation* (Vol. 1). https://doi.org/10.1136/bmj.1.4975.1098

Várhelyi, A., Kaufmann, C., & Persson, A. (2015). User-related assessment of a Driver Assistance System for Continuous Support - A field trial. *Transportation Research Part F: Traffic Psychology and Behaviour*, *30*, 128–144. https://doi.org/10.1016/j.trf.2015.02.008

Vogelpohl, T., Kühn, M., Hummel, T., Gehlert, T., & Vollrath, M. (2018). Transitioning to manual driving requires additional time after automation deactivation. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 464–482. https://doi.org/10.1016/j.trf.2018.03.019

Vollrath, M., Schleicher, S., & Gelau, C. (2011). The influence of Cruise Control and Adaptive Cruise Control on driving behaviour - A driving simulator study. *Accident Analysis and Prevention*, *43*(3), 1134–1139. https://doi.org/10.1016/j.aap.2010.12.023

van der Horst, R. (2012) Resilience to failure and breakdown. In J. Theeuwes, R. van der Horst, & M. Kuiken, Designhing Safe Road Systems: A human factors perspective. Ashgate: UK, pp 27-40.

Wallis, G., & Bülthoff, H. (2000). What's scene and not seen: Influences of movement and task upon what we see. *Visual Cognition*, *7*(1–3), 175–190. https://doi.org/10.1080/135062800394757

Wegman, F., Dijkstra, A., Schermers, G., & van Vliet, P. (2005). Sustainable Safety in the Netherlands : the vision , the implementation and the safety effects. *International Symposium on Highway Geometric Design*, 1–23. https://www.swov.nl/sites/default/files/publicaties/rapport/r-2005-05.pdf

Weijermars, W., & Wegman, F. (2011). Ten years of sustainable safety in the Netherlands. An assessment. *Transportation Research Record*, (2213), 1–8. https://doi.org/10.3141/2213-01

World Health Organisation (WHO), (2009). *Global status report on road safety: time for action*. Geneva, World Health Organization, 2009 (www.who.int/violence_injury_prevention/road_safety_status/2009).

World Health Organization; 2018. Global status report on road safety 2018. Geneva, World Health Organization; 2018, https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/

Woods, D. D., Dekker, S., Cook, R., Johannesen, L., & Sarter, N. (2012). *Behind human error, second edition*. *Behind Human Error* (2nd ed.). Farnham: Ashgate Publishing Ltd.

Woolley, J & Crozier, J. (2018) *Inquiry into the National Road Safety Strategy 2011-2020*, Australian Department of Infrastructure, Regional Development and Cities, September 2018

Wundersitz, L., Baldock, M., Raftery, S. (2014). The relative contribution of system failures and extreme behaviour in South Australian crashes. *Accident Analysis and Prevention*, *73*, 163–169. https://doi.org/10.1016/j.aap.2014.09.007

Yao, Y., Carsten, O., & Hibberd, D. (2020). A close examination of speed limit credibility and compliance on UK roads. *IATSS Research*, *44*(1), 17–29. https://doi.org/10.1016/j.iatssr.2019.05.003

Zeeb, K., Buchner, A., & Schrauf, M. (2016). Is take-over time all that matters? the impact of visual-cognitive load on driver take-over quality after conditionally automated driving. *Accident Analysis and Prevention*, *92*, 230–239. https://doi.org/10.1016/j.aap.2016.04.002