# Where are we on driver distraction? Methods, approaches and recommendations

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## Abstract

Research within the road transport domain is progressively recognising the importance of taking a systems view of accident analysis. This signals a movement away from the more traditional approaches that aim to determine cause-effect relationships and attribute blame to the end user. The multiple accidents associated with distracted driving have typically sought to establish the role of the driver and attribute responsibility to the individual. This paper will look at the approach that has been used to study distracted driving, the methods employed to study it and the recommendations they have provided to practise. The role of rapidly developing technology is discussed as more sources of distraction are presented to the driver. The limitations of the current approach lead to the proposition of a systems approach to driver distraction that aligns with the study of safety in other domains. This paper provides a novel overview of the variety of methodologies used to study distracted driving and how they may impact on the resulting countermeasures. The suggestion of a research-practise gap within the road transport domain is explored. The benefits of systems based approaches, and their place in advancing driver distraction research for the development of future recommendations, are presented.

**Key Words: Driver Distraction, Qualitative methodology, Quantitative methodology, Sociotechnical systems, In-vehicle technology**

## 1. Introduction

Human Factors, as a discipline, is largely focused around the application of methodologies to solve practical problems (Stanton et al, 2013). Human Factors methods have traditionally been applied to four main areas; design, training, safety assessment and accident investigation (Cacciabue, 2013). This has facilitated the application of Human Factors to many safety critical domains, such as aviation (e.g. Shappell & Wiegmann, 2012), health care (e.g. Reason, 1995), maritime (e.g. Baber et al, 2013), rail (Stanton & Walker, 2011) and road transport (e.g. Stanton & Salmon, 2009). A large focus within Human Factors is the recognition, assessment and analysis of error and its relationship to incident (e.g. Reason, 1990). Within the road transport domain, there is a suggestion that the view of error causation and management may be lagging behind other domains, such as aviation (Stanton & Salmon, 2009; Salmon et al, 2010). This is attributed to a lack of appropriate methods to measure and classify the errors that are made within the road transport domain which, in turn, leads to a lack of understanding for the causal factors that lead to error (Stanton & Salmon, 2009).

The systems approach is now a dominant approach in accident analysis research (Underwood & Waterson, 2013; Stanton & Harvey, 2017). Dekker (2014) argues that the role of the human has transformed from being the primary actor in the occurrence of adverse events, to the recipient of adversity that is created by the wider system. This has become increasingly poignant with the rapid development of technologies, which have also transitioned from fixed entities, to facilities that can adapt to an individuals’ strengths and limitations (Dekker, 2014). Human needs are now considered to be determined by technological advancement (Postman, 1993; Hettinger et al, 2015). Rather than controlling the individual, the advent of Human Factors research in the 21st century focuses on controlling the technology, the environment and the system that they reside in (Dekker, 2014). Reason (1990) stated that ‘human error’ was the result of a system that permits (even encourages) certain behaviours that turn out to be erroneous (with the benefit of hindsight). The notion of ‘human error’ is no longer palatable to many Human Factors researchers (e.g. Dekker, 2002). Instead of determining the human as the root cause of an incident, it is now increasingly the starting point from which to begin investigating accident causation in order to realise the other factors that influence human performance. The organisational and technological factors that contribute to the incident must be recognised so as not to view human behaviour in isolation from its context (Hollnagel et al, 2007). Indeed, it is now suggested that establishing safe systems is the responsibility of those who assess the risks and adverse consequences of the integration of technological advancement and automation within sociotechnical systems (Hettinger et al, 2015). Sociotechnical systems theory draws on the development of the complex system approach which argues against looking towards individual elements and values the interactions between multiple elements comprising a system and the wider environment within which they are located (Von Bertalanffy, 1968). A sociotechnical system is one that has both social-organisational and technical components that can be viewed as interdependent, working towards common goals for joint optimisation (Trist & Emery, 2005; Walker et al, 2008). The road transport system is considered a sociotechnical system on these grounds (Larsson et al, 2010).

While systems thinking has been integrated into the methods used to assess accidents within other domains, such as aviation (Shappell & Wiegmann, 2012), its role in providing effective countermeasures to driver error has lagged behind (Stanton & Salmon, 2009). Although the benefits it may have in reviewing error causation and developing effective countermeasures are beginning to be recognised (Stanton & Salmon, 2009; Salmon et al, 2012a; Young & Salmon, 2012; Hughes et al, 2015), the application of these into effective road safety measures is limited. Systems thinking has been considered in relation to specific areas of concern within road safety, such as situational awareness (Salmon et al, 2012b), young drivers (Scott-Parker et al, 2015) and road freight accidents (Newnam & Goode, 2015). It’s application to driver distraction has aligned with the increasing prevalence of technologies in the vehicle that has highlighted the complexity of the interacting actors that influence distraction related events (Young & Salmon, 2015; Lansdown et al, 2015; Parnell et al, 2016). Yet, while the benefits have been realised, this has yet to transcend into effective systemic countermeasures (Parnell et al, 2017).

Driver distraction is a behaviour that features within many efforts in the literature to classify driving errors (e.g. Reason et al, 2009; Wierwille et al, 2002; Sabey & Taylor, 1990). A review of human error taxonomies in the road domain have, however, suggested that distraction is not an error in itself but that errors occur as result of being distracted (Stanton & Salmon, 2009). A popular definition of driver distraction states it to be the *“diversion of attention away from activities critical for safe driving towards a competing activity”* (Lee et al, 2008:38). This suggests that distracted drivers engage their attention away from the driving task, but it does not infer that error or incident arises from this, although risk is likely to increase (Redelmeier & Tibshirani, 1997). Indeed, the reduced performance that is associated with driver distraction which impairs the the drivers’ visual monitoring of the road (Reimer, 2009) and vehicle control (Törnros & Bolling, 2005), is a complex issue that has highlighted the need to explore its relationship to driving error (Young & Salmon, 2012). It is often only with hindsight that distraction is recognised, once adverse events have occurred, only then does it become evident what the driver was, or was not, paying attention to and how the incident could have been avoided (Kircher et al, 2017). This also suggests that on many occasions drivers can divert their attention away from the road, defining them to be distracted, without this having an impact on the driving task or resulting in incident (Kircher & Ahlström, 2016). These features of the behaviour make it very difficult to capture or to determine the scale of the problem. The relationship between driver distraction and the mechanisms through which distraction may lead to erroneous behaviour are still unclear (Young & Salmon, 2012).

While some consider driver distraction to be the result of inattention and a consequence of the drivers’ finite attentional resources (Wickens, 2002), the active role of the driver in managing their attention is increasingly recognised (Cnossen et al, 2000). This perspective suggests that drivers’ structure their performance by adapting their behaviour to be consistent with the demands of the task, predominantly by slowing down to increase headway and time to collision (Noy, 1989; Hockey, 1997; Cnossen et al, 2000). Yet, the importance of a systems-based approach which does not study driver behaviour in isolation but accounts for the wider sociotechnical system within which the behaviour occurs should be realised (Stanton & Salmon, 2009; Young & Salmon, 2012). Young and Salmon (2012) advocate that a systems approach is needed to address the relationship between distraction and error within the road transport domain. A recent attempt to determine the mechanisms of driver distraction and their relationship to driving error has utilised the systems approach to suggest that elements outside of the drivers’ control may be impacting on mechanisms that results in distraction, such as device manufacturers and even current legislation (Parnell et al, 2016; 2017). As technologies are increasingly depended upon in modern society, the impact they have on road safety must be realised.

### 1.1 In-vehicle technology developments and driver distraction

Dekker (2011) highlights the issue of ‘unruly technologies’ in complex systems, whereby technological advancement is outrunning the theories and countermeasures that can manage them. The ‘unruly’ aspect of technology refers to their unanticipated emergent behaviour through interactions with other elements in complex systems which are not adequately controlled for (Dekker, 2011). The road transport domain has seen many new technologies introduced over the last few decades, as have drivers who now have many technological interactions available to them, both built into the vehicle and portable devices that they bring into the vehicle. Hand-held mobile phones have been the focus of safety concerns since their introduction and consequent wide spread use. They have challenged road safety to the extent that legislation across many countries in Europe, Australia, New Zealand, Japan, India and a large proportion of states in the USA have banned their use in the vehicle. This is not, however, the only technology that drivers have available to them, the availability of functionalities built-in to infotainment systems in the vehicle have become incrementally more advanced over time, inviting the driver to perform more complex interactions (Harvey & Stanton, 2013). Yet, legislation has not kept pace with this and other technologies are entering the vehicle that are not specifically banned by law, despite evidence to suggest that they also impair the drivers’ attention towards the road. These include mp3 players (Lee et al, 2012), sat-nav’s (Tsimhoni et al, 2004) and hands-free communication devices (Horrey & Wickens, 2002). Furthermore, as technology continues to advance with the advent of wearable technologies this imposes an increased threat of driver distraction (e.g. Sawyer et al, 2014). Hettinger et al, (2015) state that technology is evolving and being implemented into sociotechnical systems simply because it is novel and progressive, rather than due to the necessity or utility that it may have. Furthermore, those who develop and implement such technologies are not best placed to assess the impact they may have on society (Hettinger et al, 2015). It is, therefore, important to fully recognise the role of technologies within sociotechnical systems, such as that of road transport, and how they may be adversely impacting the safety of the system and balance this with the benefits that they may provide.

Within the Human Factors domain, it has been suggested that despite a change in perspective towards accident causation, the application of methodological tools to assess accidents have been found lacking (Leveson, 2011; Salmon et al, 2017; Shorrock & Williams, 2016), with a research-practice gap linked to impeding the benefits of a sociotechnical system approach to safety (Underwood & Waterson, 2013). This paper provides a review the prominent research methods used to assess driver distraction, with particular interest in the technologies available in vehicles, and the influence of these methods on mitigation strategies. This will explore the relationship between research and practise in the domain of driver distraction to determine how it may be impacting on the mitigation of distraction. The utility of the sociotechnical systems approach is considered as it becomes increasingly prominent within the road safety domain.

## 2. Methods of studying driver distraction

As the issue of driver distraction on the roads become increasingly apparent, Ergonomics researchers have utilised a range of methods and measures to study the behaviour. This has targeted multiple sources of distraction, including those external to the vehicle (Dukic et al, 2013), internal thoughts of the driver (He et al, 2011) and, most notably in recent years, mobile phones (see McCartt et al, 2006 for a review), as well as other technologies (e.g. Lee et al, 2012; Tsimhoni et al, 2004). There are, however, several issues that researchers face in trying to study the phenomenon. These relate in nature to the reason why the area is of interest in the first place, predominately its effect on road safety (Young et al, 2008). Facilitating the study of the behaviour in a naturalistic setting has potential safety implications which likely conflict with the ethical governance and risk assessments research must undergo. Driving simulators, however, provide a safe and highly controlled environment from which to examine distraction and the drivers’ response to it. Advances in technology have enabled the development of increasingly improved simulator fidelity and validity with movement from desktops to full car simulators coupled with simulation software that enables high graphical realism (Young & Lenne, 2017, 2017).

Driving simulators have advanced understanding into how secondary task engagement while driving results in reduced hazard detection (Summala et al, 1998), poor vehicle control (Tsimhoni et al, 2004), attention tunnelling (Reimer, 2009), slower resumption of control (Eriksson & Stanton, 2017), and the compensatory mechanisms employed by drivers, such as slowing down and reducing driving performance goals (Alm & Nilsson, 1995). Research has also quantified the duration of potentially distracting tasks to be those requiring more than 15 seconds of attention in total, comprising of no more than individual chunks of 2 seconds (Green, 1999; Society of Automotive Engineers, 2002). This quantification of distraction has highlighted the disruption of technologies such as mobile phones that allow the user to engage in calls, messaging, social media and even photo taking while driving and thus gratifying the ban on the use of the device while driving in many countries since its widespread use (McCartt et al, 2006). Yet, Harvey and Stanton (2013) also found that entering a destination into a sat-nav, a task that is still permitted by many devices, took longer than 15 seconds on average to complete. Furthermore, such highly controlled experimentation does not provide the context surrounding drivers’ engagement with technology, which plays a role in the safety-critical nature of interactions with secondary tasks (Harvey et al, 2011). It has tended to observe what happens once a distraction has been engaged with instead of how the distraction came about in the first instance. Alternative methods are required to gain an understanding for people’s experience of distraction, their opinions, knowledge and perception of the behaviour (Ercikan & Roth, 2006). Such approaches are associated with more qualitative and subjective research.

Moreover, as technologies introduce more complexity into the already complex system of road transport (Dekker, 2011; Salmon et al, 2012a), it is important to understand the implications that technological development has on the wider sociotechnical system. The driving task is touted to become increasingly ‘technology centric’ in the future (Salmon et al, 2012a), therefore methods that are capable of assessing the interaction of multiple actors in the road transport system are required. This includes those actors who influence the design, interaction and presence of the technology in the vehicle. These methods should assess how these actors are enhancing, or hampering, the safe functioning of the road transport system. The systems approach highlights the importance of understanding the shared responsibility for safety, with accidents perceived to emerge from normal behaviour that has evolved over time through interactions with a host of actors, from policy makers down to the surrounding contextual environment factors (Rasmussen, 1997). The theoretical approach applied, and methods used, to study behaviour have important consequences to the ways in which the behaviour is viewed and managed (Salmon et al, 2012a; Salmon et al, 2017).

### 2.1. Classification of methodologies

The distinction between quantitative and qualitative research is embedded within the Social Sciences and has contributed to distinct research fields and methodologies (Ercikan & Roth, 2006). Quantitative data is deemed to be that which can be measured and quantified whereas qualitative research seeks out non-numerical data that is more descriptive. Yet, it is important to note that the classification of research as being quantitative or qualitative is not always straight forward (Denzin & Lincoln, 2011). A second, objective/subjective, dichotomy adds another level to research methodology categorisation. Subjective data relates to the individual’s personal judgements and opinions, whereas objective data involves impartial measurement of performance (or other metrics). These objective/subjective research foundations feature in both qualitative and quantitative research. The implications that subjective, objective, qualitative or quantitative methodologies that are used to study behaviour are important to realise, as they inform the type of data that can be collected and the knowledge that can be obtained. This is illustrated with an example in Table 1.

[Insert Table 1 here]

The range of methods that have been used to study driver distraction are presented in Table 2. The role that these methods have in the development of knowledge into driver distraction and its mitigation, as well as their advantages and disadvantages are discussed below. This is by no means intended to encompass all methods that have been applied within the research field, but it does include those that have proved popular. It also shows how the methods fit into the distinct qualitative/quantitative and objective/subjective dichotomies that have been highlighted, to show how the different methods inform different data outputs.

[Insert Table 2 here]

#### 2.1.1 Objective Quantitative methods: Measuring behaviours

The use of objective, quantitative measures are popular in the field of driver distraction as they enable the quantification of specific behaviours in order to determine when distraction occurs and how it can affect driver performance and road safety (Young et al, 2008). For example, the measurement of driver performance when engaging with new technologies draws on these methods to determine if they are safe to place in the vehicle. This has been used to inform design recommendations (e.g. Green, 1999) and legislation in the case of mobile phones. The use of simulators has allowed high control within such experimentation but subsequently suffers from a lack of realism and limited application to real world driving conditions (Young et al, 2008). The use of test tracks offers a balance of both real world driving and high levels of control, but without the interactions with other road users within the road transport system the validity of findings can be reduced. Some studies have been able to research driver engagement with distractions in the real world setting (see Carsten, et al 2013 for a review). Harbluck et al (2007a), asked driver to interact with a road legal hands-free mobile phone device that did not require them to take their visual attention away from the road while they recorded their visual behaviour with a head mounted eye tracker. They conducted the experiment on real roads. While their results had increased ecological validity, due to the on-road setting, and allowed for the inclusion of their interactions with other road users, their results were limited by the participants being aware they were being studied. The researchers noted that participants “exhibited considerable safety-relevant changes in their behaviour” (p378; Harbluck et al, 2007a). The interaction of the complex environmental conditions surrounding the road transport system are difficult to imitate under the controlled conditions required for experimental manipulation (Carsten et al, 2013). It is therefore suggested that on-road methods should be integrated with other methodologies (Carsten et al, 2013).

Multiple tasks have been developed to simulate the drivers’ ability to engage with secondary tasks while driving, such as the peripheral detection task (PDT) which presents drivers with visual stimuli at different eccentricities from their central line of sight at random intervals while driving. The drivers’ response time to detect these stimuli is used as a measured of their spare visual attention. Driving related tasks have also been used, such as the car following task that requires drivers to follow a lead vehicle while engaging with a secondary task which enables the drivers’ headway to be measured to assess their safety margin and interactions with the other road user. The gap detection tasks also assess the drivers’ driving ability by asking them to judge the size of a gap in the traffic while concurrently engaging with a secondary task. Whilst these have become well practised methods, they have limited ecological validity. Tasks given to drivers under highly controlled conditions do not encounter the same motivation and desire to engage as in the real world when the driver is, for example, running late for a meeting and needs to call someone and let them know.

#### 2.1.2 Qualitative objective methods: Observing behaviours

Qualitative, objective, methods are popular in understanding the magnitude of the issue of driver distraction and the exposure that drivers have to it (e.g. McCartt et al, 2006). These methods offer a solution to the researcher effect as well as high ecological validity by providing a way of measuring the behaviour from afar, using methods to capture large data sets of drivers going about their everyday routines. This is useful as it can inform on the scale of distraction, for example the estimated number of drivers still found to be using mobile phones despite their ban (McCartt & Geary, 2004). This can then inform future countermeasures to control the issue. For example, figures corresponding to the number of incidents and fatalities caused by mobile phones is useful data when proposing new bans and increased penalties on the use of the device (e.g. DfT, 2017). Observations and incident reports, however, suffer from under-reporting issues as not all distractions can be easily observed (Sullman, 2012) and only incidents that are severe enough to be reported are included, which is likely to be only a small subsection of distracting incidents (e.g. Goodman et al, 1999).

#### 2.1.3 Subjective quantitative methods: Measuring opinions

Subjective measures are more concerned with the drivers’ perceptions of their behaviour and their potential to become distracted. There has been less focus on the drivers own views of distraction within the literature (Young & Lennè, 2010). Yet, obtaining data on the drivers’ perceptions, attitudes and willingness to engage in distracting tasks is important to understand the drivers’ motivation to behave in a way that may lead to distraction. The use of Likert scales and surveys provide access to the drivers self-reported perceptions as rankings across predetermined measures, which can then be quantitatively analysed. The identification of the drivers’ perception of risk has been linked to their willingness to engage through such methods (e.g. Nelson et al, 2009). Young & Lennè (2010) showed that drivers are aware of the risks of engaging with mobile phones while driving, yet report that they use them anyway. Access to the drivers underlying attitudes and perceptions can be targeted by media campaigns and road safety charities to increase risk perceptions and dissuade drivers from engaging in antisocial behaviour. For example, the Department for Transport run campaigns through their THINK! website and road safety resources to establish their road safety message in the UK. Yet, the use of ranking scales can be quite prescriptive as they force the driver to comment and rank aspects of their behaviour that are predetermined by the researchers’ agenda, rather than concepts they themselves deem to be important (O'Cathain & Thomas, 2004). This can then lead to misleading recommendations that may not represent the drivers own perspective.

#### 2.1.4 Subjective qualitative methods: Observing opinions

The application of qualitative methods to access the subjective view of the driver through interviews and focus groups offers an opportunity to understand the drivers’ motivations and personal beliefs surrounding the use of distracting tasks while diving, with richer data sets that can then be analysed and applied to develop or support theories of behaviour (e.g. Lerner, 2005). This allows drivers to comment on the concepts that they deem themselves to be important to distraction, rather than being swayed by the researchers’ agenda. As well as understanding how distraction occurs as the result of secondary task engagement while driving through the objective measures of distraction, an understanding for why drivers come to be distracted in the first place can also be targeted. This is a key question within the phenomenon that is less pursued (Young & Lennè, 2010). While the use of such methods have been applied to a lesser to degree more generally to road safety than the other methods, the use of interviews by Musslewhite et al (2010) focused specifically on older drivers and was able to target their perceptions of certain driving tasks. Musselwhite et al, (2010) suggest that the use of such qualitative methods may enable older drivers to discuss and become aware of their driving limitations by allowing them to reflect on their behaviour. Furthermore, Lerner (2005) conducted focus groups to facilitate the discussion of the use of different technologies by drivers of different ages. An on-road study run in parallel to the focus groups allowed drivers to discuss their decision to engage with potentially distracting tasks (Lerner, 2005). This method of data collection can inform countermeasures that wish to mitigate the drivers desire to engage in distractions while driving (e.g. media campaigns, education, training) and therefore target the source of the issue, rather than focusing on the outcome of distraction incidents which are often reviewed with hindsight (Kircher et al, 2013. Yet, again caution is required not to let this be influenced by the presence and views of the researcher as subjective views of the driver surrounding behaviours that may be deemed as illegal, such as using a mobile phone while driving, which can influence disclosure. Therefore, anonymity and confidentiality need to be assured.

## 3. A systems approach to driver distraction

Ergonomics researchers have sourced multiple methods from which to study the phenomenon of driver distraction. Indeed, due to the complexity of the phenomenon it is recommended that multiple methods are employed to explore all aspects of the behaviour (Carsten et al, 2013). Furthermore, it has also been realised that to fully understand the behaviour, and its relationship to driver error, the contribution of the wider system within which the behaviour occurs needs to be realised (Stanton & Salmon, 2009; Young & Salmon, 2012). Young and Salmon (2012) state that methods that have been used to asses this relationship have focused too heavily on cause/effect relationships that focus on driver performance measures (i.e. the quantitative/objective methods in Table 2). Hettinger et al (2005) highlight that the traditional methodologies that aim to experimentally control confounding variables to assess the effect of one, or more, variable on another is the antithesis of complex system thinking. Complex systems are defined by their interdependence of complexly interacting factors, their adaptability and their inclusion of the wider context surrounding the system. Therefore, assessing accidents through the assessment of singular root causes in limiting (Leveson, 2012). The traditional methods that impose strict experimental control over confounding variables in controlled environments contradicts the principals of complex systems thinking (Hettinger et al, 2015). The application of traditional, epistemological methods in isolation, without accounting for the role of external factors, does not allow for an insight into the impact of the wider system on the behaviour. Assessing external variables, such as environment complexity which can be manipulated in simulator studies, or integrating methods to review the impact of workload on task engagement across situations may, however, reveal the contribution of other factors in the development of error. Yet, methods to accurately depict errors within the road transport domain have lagged behind other domains (Stanton & Salmon, 2009). This has led to an over representation of the role of the driver in accident causation, rather than how the conditions surrounding the event may have facilitated error. This, in turn, is why countermeasures to prevent accidents within the road transport domain have tended to focus on changing the behaviour of the driver, rather than making adjustments to the wider system. An argument to further the study of the sociotechnical system within which driver distraction emerges in order to improve the recommendations to practise that can be made is presented here.

Legislation is a key strategy that is currently used to counter mobile phone based distractions. For example, in the UK there are continued reports of persistent engagement with mobile phone devices and phone related road incidents (Office for National Statistics, 2013; RAC, 2013). The UK banned the use of mobile phones by drivers in 2003, yet over a decade later, the issue of driver distraction remains an issue for road safety management with 1.6% of drivers across England and Scotland observed to be on their phones in 2014 (DfT, 2017). As there were 45.5 million active driving licenses on record at the time of this assessment (DVLA, 2015), this represents a large numbers of drivers who are continuing to use their phones illegally whilst driving. In 2015, 101 fatalities were attributed to distracted drivers (DfT, 2016). Rather than seeking to explore why drivers continued to use their mobile phones despite the legal consequences for doing so, the UK government has increased the penalties drivers face if they are caught using their phone while driving. The penalties were initially increased in 2007 from £30 to £60 and again in 2013 to £100. From March 2017 the penalties driver’s received for using a mobile phone doubled again to 6 penalty points on their license and a £200 fine. In the UK 12 penalty points results in an automatic ban from driving for 12 months. A recent report in the media (from data on phone use since the new legislation became effective through the Press Association under the Freedom of Information (FOI) Act stated that nearly 6000 drivers were caught using their devices in the four weeks post the new legislation change (BBC, 2017).

These reports from the UK suggest that the implementation of new policy to target driver behaviour is not a quick fix, nor is it likely to ensure any long-term change in behaviour. In line other areas of safety management (Dekker, 2002), it is now realised that such individual focused approaches to mitigating driver distraction have limited success (Tingvall et al, 2009; Young et al, 2013). Focusing on singular sources as the root cause of distraction, such as the driver and the mobile phone, ignores situational circumstances and other actors surrounding the interaction at all system levels, including mobile phone companies, law enforcers and the wider social and cultural context (Young & Salmon, 2015). It is therefore suggested that research that is able to capture the interdependence between multiple actors within the sociotechnical system that influence the emergence of the behaviour needs to be conducted to inform alternative recommendations for countering driver distraction.

A country that is striving to adopt a better perspective to road safety is Sweden, who have a different approach to driver distraction from mobile phones than most other countries globally. The Swedish government chose not to adopt a specific ban on hand-held devices by drivers, based on research into the effects phone use on crash risk (see Kircher et al, 2013). Moreover, is argued that the use of laws to ban mobile phones will likely resolve in the use of alternatives such as hands-free devices which have not been found to be any less distracting then the hand-held alternative (Horrey & Wickens, 2006). Kircher et al (2013) stated that a driver who cannot phone someone to say they are running late may induce stress and deteriorated driving, while having the phone off and being inaccessible may cause drivers to become preoccupied if they feel someone is trying to get hold of them. Sweden’s’ approach to road safety more generally has attracted the focus of many in the research domain (e.g. Elvik, 1999; Rosencrantz et al, 2007; Johansson, 2009; Larsson et al, 2010). Sweden passed a bill on traffic safety in 1997 called ‘Vision Zero’ that stated their intention to ensure that ‘eventually’ no one will be killed or seriously injured in the road transport system (Johansson, 2009). This bill strived to pursue alternative avenues to mitigate road accidents that are more in-keeping with modern views of safety management and systems thinking in other domains e.g. aviation. One way in which it did this was to divide responsibility for maintaining road safety across the designers of the system as well as the users of the system. This aims to provide solutions to road safety through improving infrastructure and road system design; moving away from the role of ‘human error’ and a focus on the individual, towards the interaction of multiple factors and designing with the human biological tolerance and limitations in mind (Swedish Road Administration, 2008 cited in Larsson et al, 2010). While the approach has already seen reductions in the number of fatality rates attributed to the road transport domain (Johansson, 2009), there is a discussion on whether the approach is actually truly systems focused (Hughes et al, 2015). A comparison of the national road safety campaigns in Sweden, the UK, Netherlands and Australia in Hughes et al (2015), failed to discern that any of these countries were providing a road safety approach that was truly grounded in the systems thinking. Although road safety practitioners in countries such as Sweden are striving to achieve a systems approach, the interactions between the components that constitute the system are ignored, lacking the insight of interdependence that is integral to a systems approach.

Much work is still required to develop the systems approach within the road transport domain. It requires methods, or a combination of methods, that assess how the driver interacts with the sociotechnical system, as well as how the sociotechnical system interacts with the driver. While the use of the methodologies detailed in Table 2 highlight the drivers’ capacity to manage distraction and their exposure to it under specific circumstances, the causal factors and progression towards accidents in the real world are less well understood (Young & Lennè, 2010). The methods presented in Table 2 provide insights into the individual facets of the drivers’ characteristics, technology design factors and the influence of specific environmental factors. Yet, the study of these in isolation, without awareness for the complexly interacting systems factors that influence the behaviour, will only lead to recommendations that are limited to the conditions under study, not those present in the real world.

Sociotechnical systems researchers have developed their own models from which to understand accident causations (e.g. Rasmussen, 1997; Weigman & Shappell, 2003; Leveson, 2004; Walker et al, 2007; Stanton & Harvey, 2017). While they too have some issues to iron out (Salmon et al, 2017; Underwood & Waterson, 2013), they are touted to provide an alternative way of assessing safety critical behaviours such as driver distraction (Tingvall et al, 2009; Young et al, 2013). Young and Salmon (2015) state that there is a “*clear role for methodologies underpinned by systems thinking*” (p358) in driver distraction research and that this is only compounded by the increasing prevalence of technology within the road transport system. Salmon et al (2012) highlight three popular accident causation models that offer the potential to review the sociotechnical system surrounding safety critical behaviours. The insights that have been generated from these models in their application to transportation safety are presented in Table 3.

[Insert Table 3 here]

The outcomes of the studies identified in Table 3 offer different insights to the contribution of accidents and recommendations for their prevention than those presented in Table 2. The implications of the wider system in accident causation are evident which allows them to offer novel recommendations to practise. Young and Salmon (2015), were one of the first research teams to apply systems based methods to driver distraction with an Accimap analysis. Accimap analysis seeks to explore the casual elements and interactions when reviewing incidents by identifying all actors within the sociotechnical system and their interactions with each other in the progression towards incident. The identification of key actors and causal sequences in accident development can be used to inform preventative measures. The initial application of Accimap analysis to the domain of road safety and distracted driving successfully identified the potential for novel countermeasures to the issue (Young & Salmon, 2015). The use of the hierarchical representation of the road transport domain illustrated that targeting the driver alone is a relatively ineffective way of managing distraction. Elements at the bottom of the system, such as the end user, are poorly placed in the systemic hierarchy to establish widespread change across the system (Branford et al, 2009). By contrast, those actors/agents towards the top of the hierarchy are better positioned to facilitate wider reaching mitigation strategies. Furthermore, Parnell et al (2017) highlighted that the application of Rasmussens’ RMF (1997) to the road transport domain should incorporate elements above the government, which was originally the top level of the system in the RMF, to include national and international committees for all interactions within the system to be captured. This also highlighted how legislation directed towards mitigating distraction from mobile phones may actually be creating the conditions within the system to encourage distraction from other technologies that are not enforced by law and are therefore deemed safer alternatives, despite evidence to suggest otherwise (Redelmeier & Tibshirani, 1997).

The application of Accimap analysis to individual case studies was also demonstrated in Parnell et al (2017) who identified key systemic actors and their interaction with the system in the development of distraction related events caused by a mobile phone and a sat-nav. In the case of the mobile phone, a delivery driver is demonstrated to be subjected to pressure from their employers to make a phone call while driving. They are also encouraged to use hand-free technology which is permitted by law and thus deemed to be safer than using their handset, despite evidence to suggest this is not the case (e.g. Horrey & Wickens, 2006). These systemic pressures place the driver in position where their safe driving performance is compromised by the systems pressures and highlights the responsibility of other actors in preserving safety. Thus, although the recommendations from studies that highlight the impact of mobile phone use on the drivers’ ability to perform the driving task suggest that distraction is likely to occur, it does not identify how it can be avoided in relation to the systemic pressures. Conversely, in a sat-nav scenario a driver is informed by an intelligent road sign that there is heavy congestion ahead which motivates them to alter the route in their sat-nav. The benefit of using a sat-nav is the availability of this facility. Interaction with the sat nav is not specifically prohibited by law, unlike mobile phones, nor is there any enforced limitations of sat-nav design to prevent the driver from entering a new destination while the vehicle is in motion so the drivers is encouraged to engage with the device and find an alternative route. Research has suggested that destination entry is dangerous (Harvey & Stanton, 2013; Tsimhoni et al, 2004), yet steps to prohibit the use of devices have not yet been taken which can lead the driver to deem the task to be safe to engage in contrast to mobile phones which are prohibited (Parnell et al, 2017). Here the influence that the device manufactures and those who set standards on the safe use of technologies hold a significant level of control over the potential for distraction to occur. Furthermore, the role of the infrastructure developers who implement intelligent signage hold the potential to better direct drivers with the provision of information on alternative routes the prevents the need for the driver to alter their route.

Other popular accident causation models that allow the system surrounding the behaviour to be modelled have been applied to other domains include the Systems Theoretic Accident Model and Process (STAMP) (Leveson, 2004), and the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegman, 2012). Yet, their application to the road transport domain is sparse. Reinach and Viale (2006) applied the HFACS model to the railroad domain to assess accident causation and made modifications to the model in order for it to meet the needs of the domain (see Table 3). Other applications of the method have made similar alterations when applying the model e.g. for air traffic control (HFACS-ATC; Scarborough & Pounds, 2001) and the military (HFACS-ADF; Olsen & Shorrock, 2010). Although these models have yet to be applied to driver error in the road transport domain, their application to other domains suggests the potential to do so. This warrants future research to identify the the errors incurred by distracted driving and the causal mechanisms that result in such errors in order to identify where countermeasures should be targeted.

## 4. Recommendations

In a review of the current ergonomics methods available to researcher and practitioners Salmon et al (2017) stated: “*We require appropriate methodologies that reflect how contemporary models think about accident causation*” (Salmon et al, 2017; p196). This paper has suggested that the need for appropriate methods and theories that are in keeping with the current trends in understanding accident causation is particularly pertinent to the study of distracted driving, especially with the increasing developments in technology that are both brought-in and built-in to modern vehicles. Methods that focus on the cause/effect relationship between the driver and distraction have a tendency to focus on the adverse actions of the driver and thus have resulted in recommendations that have predominantly focused on the driver. The application of sociotechnical systems theory to the study of driver distraction can therefore allow a wider pool of actors involved in distracted driving to be considered and offer alternative countermeasures which focus on this range of actors. This will require an understanding of all causal factors that give rise to distracted driving to tackle the issue at the source, rather than once it reaches the end user. It is therefore recommended that methods of studying the behaviour are used that allow for insights into the social and technological context within which the behaviour is occurring. Methods can draw inspiration from systemic methods such as Accimaps, HFACS and STAMP which review the components of incidents in relation to their interdependence and interrelations with each other to provide safety or, conversely, create the conditions for accidents. The essence of such methods look to determine the wider system factors that are involved in the progression towards accident, therefore the mechanisms involved in the onset of driver distraction will also need to determined.

While the mechanisms behind driver distraction are not currently well researched and understood (Young & Salmon, 2012), it is advised that future research should begin to question the traditional cause-effect models that predominantly attribute road traffic accidents to singular causes such as speeding, inattention, and mobile phone use (Hughes et al, 2015). Insights gleaned from sociotechnical approaches that strive to identify the relative impact of all the actors that may influence driver distraction should be reviewed to assess how their actions relate to one another in the emergence of safety or, conversely, accidents. The implementation of driver focused methods, such as legislation, to prevent distraction have been found lacking (Parnell et al, 2017). Methodologies, or the creative combination of methodologies, are required that acknowledge the wider systemic factors surrounding driver distraction. In contrast to the isolation of methods that study the adverse effects of distraction within standardised conditions, methods that can offer the opportunity for identifying the progression towards error in relation to the wider system will facilitate the development of alternative countermeasures that may be more effective than traditional methods, which have been found lacking (Parnell et al, 2017).

As we continue to develop technologies at a rapid rate, the use of legislation that targets the use of specific technologies will only become outdated. The bans on mobile phones found across many countries now signal that the use of other technologies are comparatively safe to use. The need to develop novel countermeasures to tackle the potential for distraction from advancing technologies is required. The use of individual focused methods will not be enough; instead the interaction of those who develop, design and implement the technology needs to be assessed with respect to the wider cultural setting in which technology is introduced.

## 5. Conclusion

This paper has presented a range of methods that can, and have, been used to study driver distraction. Each has its own advantages and disadvantages. However, it is important to acknowledge that the results are limited by the methodological construction used to elicit them. This paper has suggested that popular methods have focused primarily on the objective measurements of the driver under distracting conditions, as well as striving to understand the magnitude of the issue. The insights from such research have afforded an understanding of the drivers limited information processing capacity (e.g. Green, 1999) which has informed design standards and highlighted the need for mobile phones to be banned from vehicles (see McCartt et al, 2006 for a review). Yet, as technological advancements increase at a rapid pace, the application of driver-focused research and mitigation techniques that keep up with new demands on the drivers’ attention, and incentivise safety, are required (Salmon et al, 2010; Salmon et al, 2012a; Young & Salmon, 2015; Hughes et al, 2015). Furthermore, the underlying reasons behind how distracted driving behaviours are emerging from the interaction between actors in the road transport domain has been little researched. Instead, cause/effect relationships between the driver and distraction related incidents have emerged from the application of traditional epistemological approaches to studying the behaviour. The current methods of mitigating driver distraction in countries such at the UK, predominantly reinforce the individual focused perspective of accident causation. Yet, it is proposed here that the application of methodologies that are able to gain an insight into the wider context surrounding the behaviour, be it from the creative combination of methods or the adaption of current systems-based models applied in other domains, should seek to understand the systemic actors and the pressures they exhibit to provide alternative mitigation strategies which focus responsibility beyond the driver.

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Table 1. Example of qualitative/quantitative and objective/subjective data collected using different research methodologies in studying driver distraction from reading a text message.

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|  | **Quantitative** | **Qualitative** |
| **Objective** | Reading a text took the drivers eyes away from the road for 4 seconds (e.g. eye tracking measurement) | Yes, I read text messages on my phone while driving (e.g. tick-box response to a survey). |
| **Subjective** | On a scale of 1-10, the driver rated reading a text while driving to be a 7 in terms of its distractive effects (e.g. Likert scale in a questionnaire). | I only read a text while driving if my phone is placed in the phone holder, it is switched on to loud mode and I am driving on a quiet road because it grabs my attention (e.g. debrief interview).  |

Table 2. Table showing the different methodologies used to study driver distraction with examples from the literature.

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|   | **Quantitative** | **Qualitative** |
|  | ***Measuring behaviours*** | ***Observing behaviours*** |
|  | **Method** | **Description**  | **Example** | **Method** | **Description** | **Example** |
|  | *Facilities:* |  |  |  |  |
| **Objective** | Driving Simulators | Simulators offer a high level of control and manipulation within study design while providing data on the drivers’ inputs and a safe environment to observe the effects of distraction.  | Young & Stanton (2007) | A driving simulator study was used to assess the level of interference between secondary tasks and the primary driving task. Comparing visual and spatial secondary tasks identified the comparative impact on the drivers attentional resources in the driving task | Naturalistic studies | The drivers’ naturalistic behaviour when driving on real roads is captured, usually through video recordings over periods of time. They aim to improve ecological validity by observing the behaviour as it occurs under normal circumstances. | Funkhouser & Sayer (2012) | Video recordings of 108 drivers for 6 weeks found drivers to be on the phone for 6.7% of their total driving time. |
| Test-track  | Test tracks offer more realistic driving conditions then simulators while also allowing manipulation of secondary task engagement without the safety limitations of driving on actual roads.  | Ranney et al (2005) | 21 participants drove on a test track while using voice and visual/manual interfaces. The voice system improved peripheral vision while driving but not cognitive attention.  | Observational studies | Observations of drivers can be taken from the side of the road side or through photographing drivers to determine the tasks that they are engaging with. | Sullman (2012) | Roadside observation of 7168 drivers found 14.4% of drivers to be distracted. |
| On-road studies | On-road studies can be conducted with instrumented vehicles that are set up to collect a wide range of driving performance metrics whilst also allowing interaction with real life road conditions. | Harbluck et al (2007a) | 21 drivers drove while interacting with a hands-free device. When performing more difficult tasks, visual attention was focused more centrally and less towards the instruments or traffic lights.  | Incident reports | The use of incident and crash reporting conducted by police can be used as a database from which to gain an idea of the prevalence of distracting behaviour | Lam (2002) | Distraction accounted for 3.8% of total crashes causing injury. Frequency of crashes decreased with driver age, apart from in the 30-39yrs age group who had a more pronounced incident rate. |
| *Measures:* |  |  |  |  |  |  |  |
| Physiological | Physiological measures e.g. EEG, ECG and skin conductance can be used to measure drivers’ workload while driving in simulators, test tracks or on the road.  | Healey & Picard (2005) | 24 drivers drove on the road while their electrocardiogram, electromyogram, skin conductance and respiration was recorded. Their skin conductance and heart rate were correlated to their stress levels | Cross-sectional surveys | Surveys that capture a representative sample of the driving population under investigation can capture the self-reported characteristics of drivers. | McEvoy et al (2006) | 1347 drivers reported lack of concentration, in-vehicle equipment adjustment, external objects and passengers as the most distracting tasks while driving.  |
| Performance | A variety of driving metrics can be recorded relating to the drivers’ speed, lateral control and longitudinal control of the vehicle. Driving simulators allow this data to be readily accessible.  | Strayer & Drew (2004) | 20 older and 20 younger drivers’ performance in the driving task and in a hands-free phone conversation was compared. Drivers had slower reaction times, increased their following distance and had a reduced speed recovery after breaking. | Quasi-experimental | Quasi-experimental design allows drivers to be their own baseline when comparing the effects of interventions, crashes or perceived risk before and after an event. | Redelmeier et al (1997) | Case cross over design with 699 drivers found that use of a phone while driving increased the risk of collision to four times higher than when they were not using a phone while driving. The use of hands-free phones has not safety advantage. |
| Eye tracking | The drivers’ visual behaviour is an important metric in driver distraction research to identify where the driver is directing their attention.  | Sodhi et al (2002) | Participants drove on the road wearing a head mounted eye tracker to capture eye position and pupil diameter. When tuning the radio and checking mirrors there were long off road glances, compared to checking the speedometer  | Case Studies | Studying a specific event where an accident occurred due to distraction allows the factors leading to the incident to be determined in order for lessons to be learnt.  | Parnell et al (2016) | A high-profile case of a driver who hit and killed a cyclist while driving and entering a destination in a sat-nav was reviewed to reveal the role of systemic actors in the progression of the accident.  |
| *Tasks:* |  |  |  |  |  |  |  |
| Lane change task | Drivers are repeatedly asked to perform lane changes as directed by road signs. Performance in their lane changes is compared to an ideal lane change  | Harbluk et al (2007b) | Lane change initiation and deviation of lane change path was affected by the presence and complexity of a navigation task.  | Verbal Protocol  | Verbal protocols are used to gain access to the drivers cognitive processing by asking them to ‘think aloud’ while driving. It can be used to assess situational awareness and decision making while driving. It should not adversely effect the drivers performance | Young et al (2013) | Participants were asked to drive a vehicle around a test track while they were distracted by the peripheral detection task. This was compared to a baseline drive when they were not distracted. Drivers provided verbal protocols in both drives which were used to determined that the nature of errors that made when drivers were distracted was the same as when they were not distracted, they were just more frequent.  |
| Peripheral detection task (PDT) | Drivers are presented with randomised visual stimuli at different eccentricities from central line of sight while driving. They are required to detect the stimuli as quickly as possible | Harms & Patten (2003) | Drivers were asked to drive while following a route from memory versus following a navigation system while performing the PDT. Driving behaviour was not effected by condition but PDT performance was reduced when drivers were given visual navigation messages.  |  |  |  |  |
| Car following | The ability of the driver to follow a vehicle in front through their reaction time, headway and speed allows for the driver’s attention and perception of performance to be measured | Alm & Nilsson (1995) | Drivers were asked to follow a vehicle in a driving simulation while using a mobile phone. Their reaction time increased with phone use, but drivers did not increase their headway to compensate for this reduced performance.  |  |  |  |  |
| Gap acceptance | Drivers acceptance for moving into gaps in traffic are used to measure the effect of distractions on the size of gap accepted and the number of collisions.  | Cooper & Zheng (2002) | Drivers performed the gap detection task while interacting with an in-vehicle phone providing verbal messages of varying complexity. The use of the phone and the verbal message prevented drivers from responding to the road surface conditions and limited their performance.  |  |  |  |  |
|  | Decision to engage with Secondary task  | Drivers willingness to engage with distracting tasks can be assessed to infer their ability to adapt their interaction with the driving task. Drivers are given the choice to engage with a secondary task at predetermined points of the route. Factors in the situation can be manipulated to assess how they may influence the operational, tactile and strategic level of control.  | Schömig & Metz (2012) | Drivers were asked to drive in a simulator where they were given the choice to engage with a secondary task at certain points along the route. The points reflected critical and non-critical situations. The drivers’ decision to engage, and their subsequent performance in the task, were then measured to assess how they integrated the secondary task with the driving task. This showed that drivers were able to interact with the secondary tasks in a situationally aware manner.  |  |  |  |  |
| **Subjective**  | **Quantitative** | **Qualitative** |
| ***Measuring opinions*** | ***Observing opinions*** |
| **Method** | **Description**  | **Example** | **Method** | **Description** | **Example** |
| Surveys | Surveys completed online, in person or by telephone can gain drivers self-reported engagement in distracting tasks as well as asking them to rate certain behaviours and their perceptions of tasks using Likert scales.  | White et al (2004) | Drivers ranked their self-reported behaviour and their perceived risks of a variety of in-vehicle technologies. Mobile phones were perceived as one of the riskiest tasks, yet drivers still reported to engage in the task as they perceive the risk as being greater for others than for themselves.  | Interviews | Interviews allow a researcher to ask drivers about their driving behaviour and their views on distracting tasks. Transcripts can be recorded and analysed qualitatively through inductive or deductive thematic analysis or with tools such as Leximancer. | Mussel- White & Haddad (2010) | Interviews were conducted with 29 older drivers and found that drivers stated their driving skills and attitude were better than when they were young. Yet they also found some tasks difficult such as reading road signs and maintaining speed. Interviews allowed older drivers to be more aware of their driving limitations. |
| Video ratings  | The use of video clips to represent driving conditions or scenarios can allow drivers to rate their own actions without actually driving themselves.  | Hancox et al (2013) | 20 participants were asked to rate their willingness to engage with their mobile phone across 15 video clips. Roadway demand and task functionality affected willingness to engage.  | Focus groups | Focus groups facilitate discussion between a target population on issues surrounding driver distraction to observe social interaction when discussing their behaviour. | Lerner (2005) | 45 participants were spilt into 6 focus groups of different ages to discuss their motivations, decisions, road situations and errors made when use technologies in the vehicle. |

Table 3. Table showing the systems methodologies, with examples from the literature.

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| **Method** | **Description** | **Example** | **Domain** |
| Accimap Analysis (Rasmussen, 1997) | Accimaps were founded within the Risk Management Framework (RMF; Rasmussen, 1997) that defines six hierarchical levels of a sociotechnical system that interact with one another to determine the behaviour of the sociotechnical system. Accimaps have been praised for their ability to generalise across domains while identifying links between actors and contributions to failure that stem from the top of the system (e.g. Government policy and regulators) to the bottom (e.g. end users and the environment). Their graphical representation allows system interactions to be readily visualised to inform novel countermeasures.  | Young & Salmon (2015) | Young & Salmon (2015) performed an Accimap analysis to show how countermeasures to distraction effect the levels of the sociotechnical system. This showed how measures such as intelligent lock out systems within portable devices and automated technology detectors can act as preventative measures. The benefits of these countermeasures, over more traditional alternatives that are more reductionist and focus on ‘fixing’ the driver, are revealed. The method highlighted a range of actors other than the driver with responsibility for driver distraction, including (but not limited to): road safety policy makers, media, insurance companies, employers, manufacturers and the in-vehicle devices they design.  | Driver distraction |
| Parnell et al (2017) | An Accimap analysis was applied to compare the interaction between actors in the road transport system that relate to the drivers use of mobile phones compared to other technologies available in the vehicle. This highlighted the need to expand the traditional six hierarchical levels of the RMF to include two higher level actors; the international and national committees who determine the necessary policies that national governments subscribe to when enacting laws surrounding road transport behaviour.  | Driver distraction |
| Human Factors Analysis and Classification System (HFACS; Shappell & Weiman, 2012) | HFACS is based on Reason's Swiss cheese model which looks at the interaction between latent conditions i.e. the inadequate aspects of the system) and the action of the human operator in relation to the accident. The HFACS was originally developed to apply the Swiss Cheese model to the aviation domain, with the addition of taxonomies of failures across the levels of the system; unsafe acts, pre-conditions for unsafe acts, unsafe supervision and organisational influences. It allows all levels of the system to be considered and investigated in their role in contributing to accidents.  | Reinach & Viale (2006) | The HFACS was modified to optimise its application to the railroad domain (HFACS-RR) including changing the names of the levels to fit the railroad domain, the addition of a top-level (outside factors) and adding other sub-categories where appropriate. It was then applied to 6 train accidents to assess the contributing factors. A total of 36 possible contributing factors were identified across the 6 accidents, with active failures and latent conditions apparent in all accidents. Contributing factors included technological environment factors, skill based errors such as attentional failures, poor resource management and organisational practices amongst others. The analysis allowed for low-cost improvements to be assessed to facilitate immediate benefits to railroad safety.  | Railroad accidents |
| Systems Theoretic Accident Model and Process (STAMP; Leveson, 2004) | STAMP is a control based method that asserts that a sociotechnical system is comprised of hierarchical levels of control which each have safety constraints that influence the systems potential for accident. Accidents are said to occur due to inappropriate interactions between components across the levels, external disturbances and/or failures in the components themselves.  | Kazaras et al, (2012) | STAMP was applied to the risk assessment of road tunnels and the road tunnel ventilation system in response to the high number of accidents in tunnels. The STAMP model was able to examine relationships between all elements in the tunnel system, as well as the co-operation of those responsible for tunnel safety. The STAMP model identified the benefits of system thinking in risk assessment, rather than identifying the sequence of events which gives a limited view of accident causation. Alternative methods such as tunnel design were proposed for improving road tunnel safety. | Road Tunnel safety |