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What's the law got to do with it? Legislation regarding in-vehicle technology use and its impact on driver distraction

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ABSTRACT

Legislation in the road transport domain aims to control safety on the roads. Despite this, a critical issue affecting road safety is that of driver distraction. Although poorly defined, distraction is a significant road safety issue which, in part, is caused by the prevalence of technology within vehicles. Legislation surrounding the use of in-vehicle technologies are explored in this paper from a socio-technical system perspective. This reveals the wider context of the road transport system operating under the current laws using an Accimap analysis. A distinction in the law between the use of hand-held mobile phones, a device that is typically banned for use by drivers worldwide, and the use of other technological devices that are covered by more general laws against 'careless' and/or 'dangerous' driving was found. Historically, individual drivers' have been blamed for distraction, whereas the systems approach shows how current legislation may have created the conditions necessary for driver distraction.

1. Introduction

Since the invention of the modern motor car in the late 1800's and its widespread use from the early 1900's, there have been many developments to the road environment, infrastructure, vehicles, in-vehicle technology, licensure and driver training. Legislation must respond to these changes to ensure safety is maintained alongside new developments. Policies titled "Tomorrows Road: safer for everyone" (DfT, 2000) in the UK and 'Vision Zero' (Tingvall and Haworth, 2000) in Sweden infer that legislation is striving to improve road safety in the future.

Road safety is threatened by a number of issues, predominately drink driving, wearing a seatbelt, motorcycle helmets, speeding and driver distraction (WHO, 2016). Driver distraction has become of increasing concern in recent years with the development of technology (Walker et al., 2001; WHO, 2011). Despite being the focus of research for many decades (e.g. Brown et al., 1969), no universal definition or approach to the issue has yet been applied (e.g. Young et al., 2007; Regan et al., 2011). One definition by Lee et al. (2008) has gained support within recent years (e.g. Liang and Lee, 2010; Young and Lennè, 2010; Hosking et al., 2009; Parnell et al., 2016), it states distraction is the "*diversion of attention away from activities critical for safe driving towards a competing activity*" (Lee et al., 2008: 38). Distractions in the form of competing activities are cited to occur from a diverse range of activities inside and outside of the vehicle (e.g. Young et al., 2008; Young et al., 2009). Yet, it is important to note that contemporary approaches to driver distraction have stated that distraction in itself is not an error but that errors occur as result of the distraction (Stanton and Salmon, 2009). In other words, drivers may engage in distracting tasks without adverse outcomes, yet research has shown the risk of incident is greatly enhanced (Redelmeier and Tibshirani, 1997; Violanti, 1998; Laberge-Nadeau et al., 2003).

The adverse impact of driver distraction on road-safety is highlighted in a recent report from the National Highway Traffic Safety Administration (NHTSA) which stated that 3179 people were killed and 431,000 people were injured in motor vehicle crashes involving a distracted driver on American roads in 2014 (NHTSA, 2016). These only include cases where distraction was actually captured in reports, the negative implication related to driver distraction suggest that these figures likely under report the true impact of the issue. NHTSA classified 13% of the distraction related fatalities to be caused by mobile phone use, a growing concern worldwide (WHO, 2016). The developments in technology have facilitated driver to be more connected (Walker et al., 2001), but phone use while driving has a significant impact on road safety (WHO, 2011). Rapid developments in technology are also cited to provide difficulties in capturing the full range of distractions (NHTSA, 2016). In-vehicle systems now provide drivers with an array of information, enter-

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tainment, and comfort features to enhance the driving experience (Harvey et al., 2011). As technology has developed, the variety and complexity of these features has increased (Walker et al., 2001). Although the statistical data related to crash risk is difficult to discern, research has shown that music devices (Lee et al., 2012), satellite navigation systems (Tsimhoni et al., 2004), wearable technologies (e.g. Sawyer et al., 2014), and even hands-free devices (Horrey and Wickens, 2002) impair drivers' attention.

Legislation and regulations must adapt to incorporate technological distractions, yet, there is critique that policy change may be somewhat of an afterthought, playing catch-up only after gaps within existing policy have been found (Leveson, 2011). With developments in technology occurring at a rapid pace it is hard for policy to regulate its use (Leveson, 2011; Redelmeier and Tibshirani, 1997). Mobile phone use in vehicles are a key example of this, their use in vehicles was questioned only after risks to road safety were proven (WHO, 2013). Since the early 2000′s drivers have been banned from using a mobile phone in many countries such as the UK, Australia, New Zealand, China, Japan, India and EU member states. In the USA and Canada, the laws around hand-held mobile phone use varies between states, with 14 states banning their use. Enforcing a ban on specific behaviours aims to target the attitudes of the road users (Chen and Donmez, 2016). Since the mobile phone ban, their use is regarded to have a higher perceived risk than other devices, which is thought to be linked to the increased publicised dangers associated with the ban (Young and Lennè, 2010). Other technological devices that are not banned within legislation are covered under general laws, using sentiments such as "*You must exercise proper control of your vehicle at all times*" (The Highway code, Rule 149), and "*devices may be used as long as it does not detrimentally impact driving behaviour*" (Trafikförordning, 1998; chapter 14.6) are applied. Compared to the definitive ban on hand-held mobile phone use, the legal perspective on the use of other technologies is less conclusive both to those who must follow it and those who must enforce it. (e.g. Young and Lennè, 2010). Therefore, there is a distinction within legislation which permits drivers to have different attitudes towards devices that are not banned to the same degree that mobile phones are. Yet research has found other technologies to be no more safe than mobile phones (e.g. Horrey and Wickens, 2004; Tsimhoni et al., 2004; Sawyer et al., 2014).

To enforce traffic safety laws, drivers are given penalties in the form of fines and points on their license when they are found to be contravening the law. In a bid to clamp down on mobile phone use while driving in the UK the Department for Transport plan to increase the current fine of £100, to £150 and the points on the license from three to four points in a hope to deter drivers (DfT, 2016). However, these techniques descend from a traditional, or 'old view' (Reason, 1990; Dekker, 2002), of accident causation, viewing the driver as unreliable and the main threat to safety (Larsson et al., 2010). Contemporary research favours the 'new' systems approach (Dekker, 2002; Reason, 1990), which considers accident causation to be a consequence of the interrelationships within the socio-technical system (Larsson et al., 2010; Leveson, 2011; Salmon et al., 2012a; Lansdown et al., 2015). Systems thinking, first developed by von Bertalanffy, states that a system should not be studied by looking at the individual elements from which it is composed as this is too simplistic. Instead, the interactions between elements and their environment should be studied to gain a more holistic view (Von Bertalanffy, 1968). The application of systems thinking to the driving domain has been considered a necessary next step in improving road safety (Salmon et al., 2012a; Lansdown et al., 2015; Parnell et al., 2016), including driver distraction (Young and Salmon, 2015).

1.1. Aim

It is evident that there is a distinction within the legislation of many countries between the use of mobile phones in vehicles compared to other technologies available to the driver. This paper aims to evaluate the current legislation surrounding the use of mobile phones and other in-vehicle technologies to gain insight into its efficacy in targeting distraction and maintaining safety with respect to the road-transport system as a whole. Paying particular attention to the systems elements involved in the use of mobile phones and other devices aims to determine what impact the distinction within legislation has on the wider road transport system and their responsibility for the emergence of distraction.

2. Method

To understand how interactions within the road transport system may result in the emergence of accidents caused by distraction, Young and Salmon (2015) applied the risk management framework (RMF, Rasmussen, 1997) to distraction-related events. From this they discerned the utility of current distraction countermeasures and the potential for improved systems-based countermeasures. This paper builds on Young and Salmon (2015), by analysing the laws surrounding in-vehicle technology use by drivers within the context of the whole road transport system. In doing so it will apply the RMF to the system surrounding the use of technologies by drivers and conduct an Accimap analysis. Adaption of the Accimap methodology aims to determine general behaviour of the system under normal functioning as Trotter et al. (2014) and Salmon et al. (In Press) have achieved in other domains. The legal framework of the UK was used for this analysis but comparisons to other countries legislation are made.

2.1. Application of the risk management framework to in-vehicle technology use

Rasmussen's RMF (1997) has been applied across multiple domains that comprise socio-technical systems such as, food safety (Cassano-Piche et al., 2009), public health (Vicente and Christoffersen, 2006), outdoor activities (Salmon et al., 2010) and road transport (Scott-Parker et al., 2015; Newnam and Goode, 2015), including driver distraction (Young and Salmon, 2015; Parnell et al., 2016). This framework typically features six hierarchical, cohesive and interactional levels of a system; the government, regulations, company, management, staff and work. A first step in assessing the impact of legislation on the system was to apply the RMF to driver distraction legislation. This is graphically represented in Fig. 1.

An initial review identified that high-level elements outside of the Government are involved in legislation development. The design and development of in-vehicle information systems is incorporated into international principals (e.g. International Organisation for standardisation, ISO) which sets the standard for all countries conforming to international committees. National bodies coordinate national standardisation, distributing responsibility across the different governmental departments to enact the ISO within national policy. In the UK the British Standards Institute (BSI) sets national standards, collectively developed by a technical committee formed of organisations, consumers, industrial bodies, researchers and other experts within the field. These contributors must come to a consensus on the standards required. The traditional six levels of Rasmussen's sociotechnical system have therefore been expanded in Fig. 1 to include an additional two levels; international and national committees. Government departments outline specific policies in line with the international and national standards, enacted by relevant government bodies such as the Department for Transport. Regulators must then control, enforce and inform device use related to legislation at the lower levels of the system. Application of the RMF to driver distraction from in-vehicle technology suggests these levels need be adapted to be more domain specific. The 'Company' level in the original RMF has been re-termed 'Industrialists' to refer to the key industrial organisations related to in-vehicle technologies and their use by drivers in the road context. These industries are comprised of the 'resource providers' the next hierarchical level, renamed from 'Management'. Resource providers include the departments involved in the development, design and provision of the resources available to drivers. The drivers and all other 'end-users' are reflected in the next level down (renamed from "staff' in the original RMF). The end users are distinct from the equipment and the environmental context they engage with, which is the bottom hierarchical level 'Equipment & Environment'.

The public opinion feedback loop is an important part of the RMF, the nature of democratic societies requires the government and policy makers to pay attention to the opinions of their citizens (Weinberger, 1999). Although, the extent to which public opinion has the ability to impact on policy is an area of contention (Burstein, 2003). Notably, the desire to engage with new technologies by drivers should not be given the same weight as the potential for traffic fatalities and incidents that may occur as a result. An additional feedback loop between the lobbyists at the industrialist level and those higher up highlights the influence that lobbyists from vehicle companies can have over legislation implementation within this domain.

Legal requirements change with time and the respective committees must ensure laws are adequate for the current climate. Systems migrate towards accidents through the natural process of adapting to pressures placed upon them (Rasmussen, 1997). Fig. 1 highlights the pressures evident in the use of in-vehicle technology. At the lower levels of the system, technological advancements develop to meet the drivers' needs and desires to remain connected while driving (Walker et al., 2001). In a bottom- up way, these impact on the automotive and technology companies, who must facilitate these advancements and driver requirements. As in-vehicle design develops it is has become an increasingly important competitive element for car manufacturers and technology companies. Yet, manufacturers must also adhere to HMI design guidelines and government standards which set the top down pressures on in-vehicle technology to ensure technological advancements are applied safely. Pressures are normal within systems but over time they can push the system too far such that efficiency risks the performance of the system as a whole. Rasmussen labelled this point as the boundary of 'functionally acceptable behaviour' (Rasmussen, 1997, p. 189). Reviewing distraction from the systems approach hopes to assess how the system may allow the efficiency of engaging with communication, information and entertainment devices while driving without yielding to distraction. To understand the workings of the system under current legislation an Accimap analysis was performed.

2.2. *Application of the accimap analysis to in-vehicle technology use*

The Accimap accident analysis methodology is often used within systems theory to graphically represent a socio-technical system to identify key causal actors and decisions in the route to incident (Rasmussen, 1997). The Accimap methodology is cited to be the most useful in analysing accidents in a safety critical domain (Salmon et al., 2012b). Yet, initial applications of the method were limited by an inability to analyse general behaviour, or explain the emergence of accidents from normal behaviour (Salmon et al., 2015). Other accident analysis methods apply to multiple events by using taxonomies e.g. The Human Factors Analysis and Classification System (HFACS; Shappell and Wiegmann, 2012) and Systems Theoretic Accident Modelling and Processes model (STAMP; Leveson, 2004). These taxonomies determine the general failure modes that are used to determine the causal events of accidents. However, HFACS is less convincing in determining accountability in the higher level factors (Salmon et al., 2012b). The benefit of the Accimap approach is that it allows for the assessment of high level factors, and this paper hopes to show its application to the international context, as has been achieved with the application of STAMP (Salmon et al., 2016b). Recent work has suggested that Accimap analysis can be adapted to infer more generalizable outcomes. Trotter et al. (2014) applied the Accimap framework to assess improvisation within socio-technical systems, and successfully evaluated negative and positive outcomes to suggest it is able to assess normal behaviour within events. Furthermore, a recent application of the method within the outdoor activities domain has shown that Accimaps and the RMF may be utilised in developing a new incident reporting and learning system within this domain, which facilitated an Accimap analysis of 226 incidents (Salmon et al., In Press).

Table 1
Definition of the PARRC model mechanisms (adapted from Parnell et al., 2016).

PARRC Mechanism of Distraction	Definition
Goal Priority	The multiple goals drivers face cannot be completed simultaneously; they need to be prioritise in accordance with goal hierarchy. It is important that the priorities match the current demands to maintain safety.
Adapt to Demands	The increased mental and physical demand associated with engaging with secondary tasks while driving requires adaption of either the primary or secondary task, or both.
Resource Constraints	Attentional resources are finite; successful driver behaviour involves manipulating resources to enable their efficient distribution between tasks and according to the situational demands
Behavioural Regulation	The self-management of attention, effort, attitudes and emotions to facilitate goal attainment.
Goal Conflict	The existence of two or more goals that come into competition with each other such that both cannot be completed concurrently without disrupting one another.

This paper proposes the application of the Accimap methodology to further develop its accountability for normal behaviour in the emergence of accidents and its application outside of singular events. In the same way that other methods use taxonomies to identify classified and general failures, here the general mechanisms of distraction from in-vehicle technology are utilised to determine how the actions and decisions made by elements within the system assist in the facilitation, or mitigation, of distraction from in-vehicle technologies. The general mechanisms of distraction from in-vehicle technology, 'Goal Priority', 'Adapt to Demands', 'Resource constraints', 'Behavioural Regulation' and 'Goal Conflict' which comprise the PARRC (priority, adapt, resource, regulate and conflict) model (Parnell et al., 2016) will be used. These five mechanisms determine the underlying characteristics of a system that make it liable to incident from in-vehicle technology (Parnell et al., 2016). The mechanisms are briefly outlines in Table 1, readers are directed to Parnell et al. (2016) for further detail.

Parnell et al. (2016) provide a preliminary exploration of the PARRC model through its application to a case study. This highlighted how each of the mechanisms played a role in the precursory events of a real life fatal incident resulting from a technological distraction. Application of systems theory to the model successfully allowed the assessment of contributing systems elements to the emergence of the incident. This is the first model of distraction to account for systems factors. The utility of the PARRC model in assessing the mechanisms through which systems elements influence the outcome of distraction related events resulting from technology use is applied here to the Accimap methodology, in a taxonomic manner. This will allow the Accimap to classify each elements failure mechanisms and their relation to the specific domain, rather than generalised taxonomies which feature in the STAMP and HFACS methodologies.

2.3. Accimap analysis

The first step in Accimap development is to formulate an actor map, locating all actors comprising the system, across Rasmussen's adapted hierarchical levels (Rasmussen, 1997). The PARRC model (Parnell et al., 2016) was formulated from a grounded theory methodology utilising literature on technological distractions from both the use of mobile phones and other devices, this literature was utilised in the Accimap development. The interrelations between each of the elements within the literature were explored, including decisions and actions made at each level. Mobile phone use and other technology use were separated and the elements and actions associated with distraction populated different Accimaps. The actor map and Accimaps were developed before being reviewed and refined by two subject matter experts with approximately 40 years of combined experience in the Human Factors Engineering domain.

In line with standard Accimap methodology (Stanton et al., 2013), each of the decisions and actions between the interrelating elements were assessed to determine the errors that had been identified, or where potential for error had been highlighted. Utilising the knowledge of the two subject matter experts, the relation of each of the systems elements across the RMF levels to the wider systems issues were determined. This then enabled the classification of systemic actions and interactions to the mechanisms of distraction highlighted in the PARRC model. This was achieved in the same way as in the case study example in the development of the PARRC model (Parnell et al., 2016). Here it was highlighted that some of the systems elements were partaking in actions and decision that were actively seeking to reduce distraction through the PARRC mechanisms, while others were leaving the system vulnerable through failing to take account for the PARRC mechanisms. For example, the media and their campaigns (e.g. THINK) aimed to target the drivers' attitudes towards different driving behaviours and theyheavily target the use of mobile phones by drivers. By highlighting the fact that the driving task is more important than the phone task they target the goal priorities of the driver. Therefore, within the mobile phone Accimap the media element was deemed to be supporting the goal priority mechanisms in mitigating distraction. However, the use of other technologies while driving has not attracted the same level of media attention, the media are therefore not setting the drivers goal priorities to the same degree within the other technologies Accimap, leaving the system vulnerable to distraction via this mechanism. A further example to illustrate the development process of the Accimap is road safety charities. Road safety charities are also regulators of legislation. Yet, unlike the media, road safety charities in the UK do provide information relating to the adverse effects of mobile phones as well as other technologies, the goal priorities of the driver are therefore targeted and supported by road safety charities in both Accimaps. Distinction between the ability of the systems elements to support the system in preventing distraction was sought and highlighted within the Accimaps through highlighting the relevant mechanisms to distraction for each systemic element. Highlighting the mechanism in black where the element is supporting the system through taking actions to protect against the specified PARRC mechanism e.g. road safety charities, or highlighting the mechanisms in grey where actions by the systems element are deemed to be facilitating of distraction via the PARRC mechanism e.g. the media in relation to other technology use. Each element was taken in turn to classify its interrelations with the other elements and assess how it impacts on the PARRC mechanisms. Both the actor map and Accimaps were developed before being reviewed and refined by the two subject matter experts.

3. Results and discussion

Development of an actor map found a total of 40 possible actors, spanning 8 hierarchical levels relating to in-vehicle technology use (see Fig. 2). This highlights an array of factors, beyond the drivers control, that must account for some level of responsibility in the maintenance of safety within the system.

The distinction between legislation on mobile phones versus other in-vehicle infotainment systems is considered using separate Accimaps (see Section 3.1 and 3.2). For clarity each of the elements is referenced with a letter to assert its level and a number to locate it across the level. The Accimaps detailed in the following Figs. 3–6 can be read both laterally and vertically along the interconnecting arrows between elements. Following the connection across the levels will illustrate how the different elements are connected.

3.1. Accimap of phone use

Fig. 3 highlights the elements that comprise the system surrounding mobile phone use in vehicles within individual boxes across the 8 identified levels of the RMF. The PARRC factors are also presented in each box. The top four levels of the system (International committees, National Committees, Government and Regulations) are shown in Fig. 3 to be effectively accounting for the PARRC factors 'Goal conflict' and 'Resource Constraints'. The international bodies state the dangers of using hand-held mobile phones, informing on the conflict that arises between the drivers' ability to attend to the road and talk on a hand-held phone at the same time (IC2-4). The European Statement of Principals (ESoP) (IC1) suggests that "*Nomadic systems should not be used hand-held or unsecured within the vehicle while driving*" (Commission of the European Communities, 2006, p238). That leads to the consideration that handheld devices are not recommended for use whilst driving (Commission of the European Communities, 2006). Yet, ESoP goes on to state that mounting the device enables better control and therefore is permitted (when conveniently placed).

National committees inform on the application of international standards into national law. In the case of mobile phone use, committees involved in technology innovation (NC3), industrial strategy (NC4), the media (NC5), as well as the transport select committee inform on national requirements. UK committees state hand-held phones should be banned. They implement legislation in the UK that prevents them from coming into conflict with the driving task, embodied by government legislation and the Road traffic act (1988) and the Road Safety Act (2006) which must then be regulated nationally (G1). The Highway code is a public document which informs all road users of the rules of the road (R3). It allows legislation to be easily accessed and understood by members of the general public in order for them to apply it. Road safety charities also act as regulators by actively informing the public on the laws of the road and how to be safe, raising awareness of the dangers of hand-held phone use and the preventative measures against distraction (R4) e.g. switch off before you drive, do not call others when driving. Other regulators include the HMI guidelines which are accessible to designers and vehicle manufacturers and must be abided by when designing technology accessible to drivers (R1). These guidelines relate to the international and British design standards (IC2, NC2). As hand-held phones are banned, HMI designs facilitate communication via hands-free devices. Device manufacturers capitalised on this gap in the market; developing hands-free

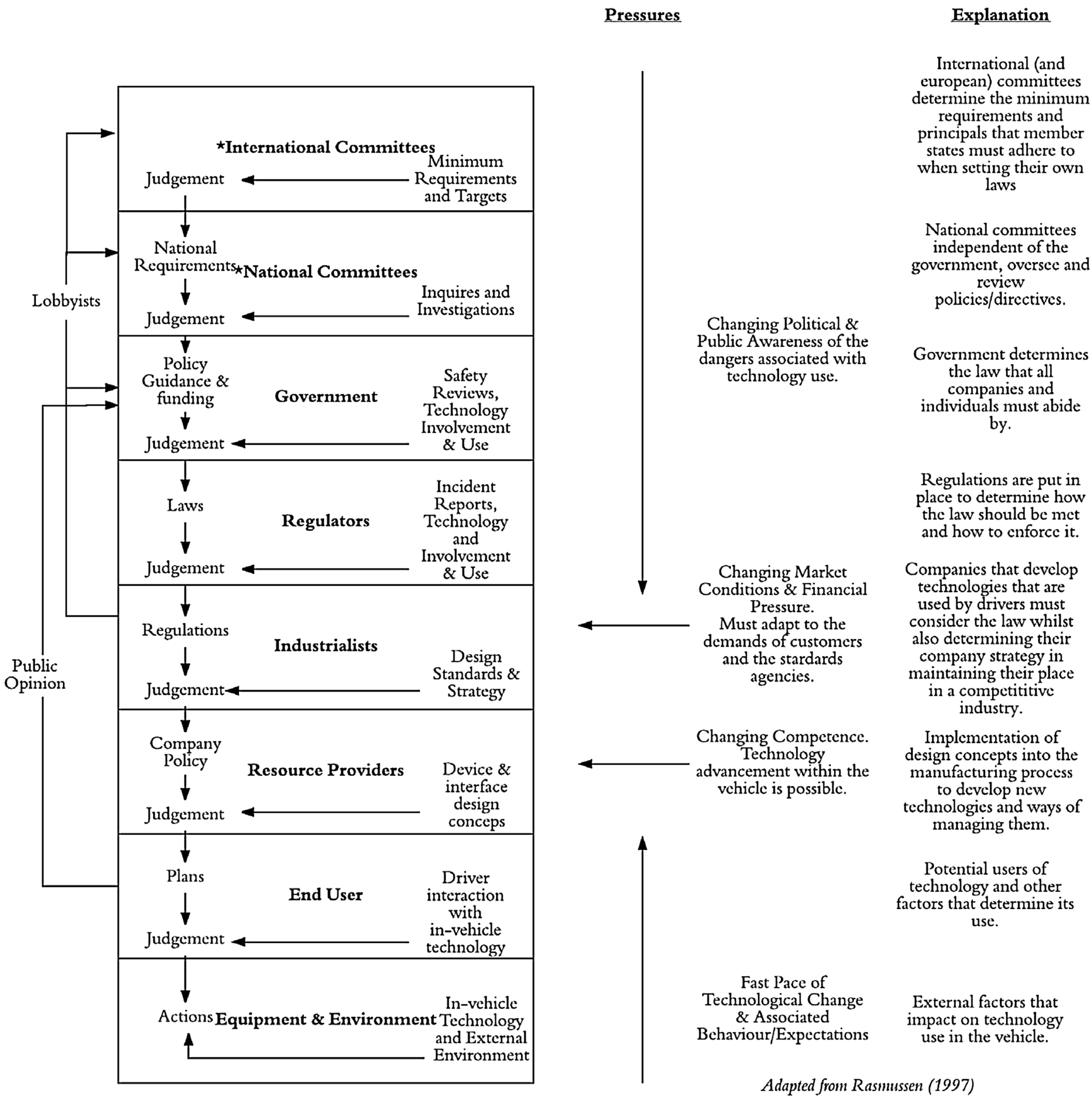

Fig. 1. An extension to Rasmussen's Risk Management Framework (1997) applied to in-vehicle technology use while driving. (* additional levels included to apply to the road transport domain).

devices to allow drivers to talk on the phone while driving, and have become very popular (C3). Vehicle manufacturers are pressured into incorporating them into the in-vehicle system design and aftermarket device manufacturers cater for those with older vehicles that do not have the facility built in (C2). These devices must be designed to meet the HMI guidelines and standards that are nationally upheld e.g. the 15 s rule, which limits the length of time it takes to complete a task on a visual manual display while driving to a total of 15 s (Green, 1999). Yet, although they may be permitted by law, they still have associated risks. Research centres suggest hands-free may be just as distracting as using hand-held phones (C6) (Redelmeier and Tibshirani, 1997; Strayer and Johnston, 2001; Horrey and Wickens, 2006). The highway code makes reference to their potential to distract yet permits their use over hand-held options. The responsibility to engage is left to the driver (M2). Yet the driver has a low perceived risk of the use of hands-free devices compared to the hand-held alternative (EU6) (Young and Lennè, 2010). Goal conflict is therefore shown to be unsupported by the system at the end-user level (EU1-11).

At the company level, actors must abide by the regulations and enforce their own company policies to ensure they are meeting regulation (C1-7). There is focus on making the use of mobile phones an undesirable option with media campaigns focusing their attention on raising the profile of the risks of mobile phones and insurance companies not covering incidents where a phone was in use (C4 & C7). This ensures that drivers' take responsibility for their actions

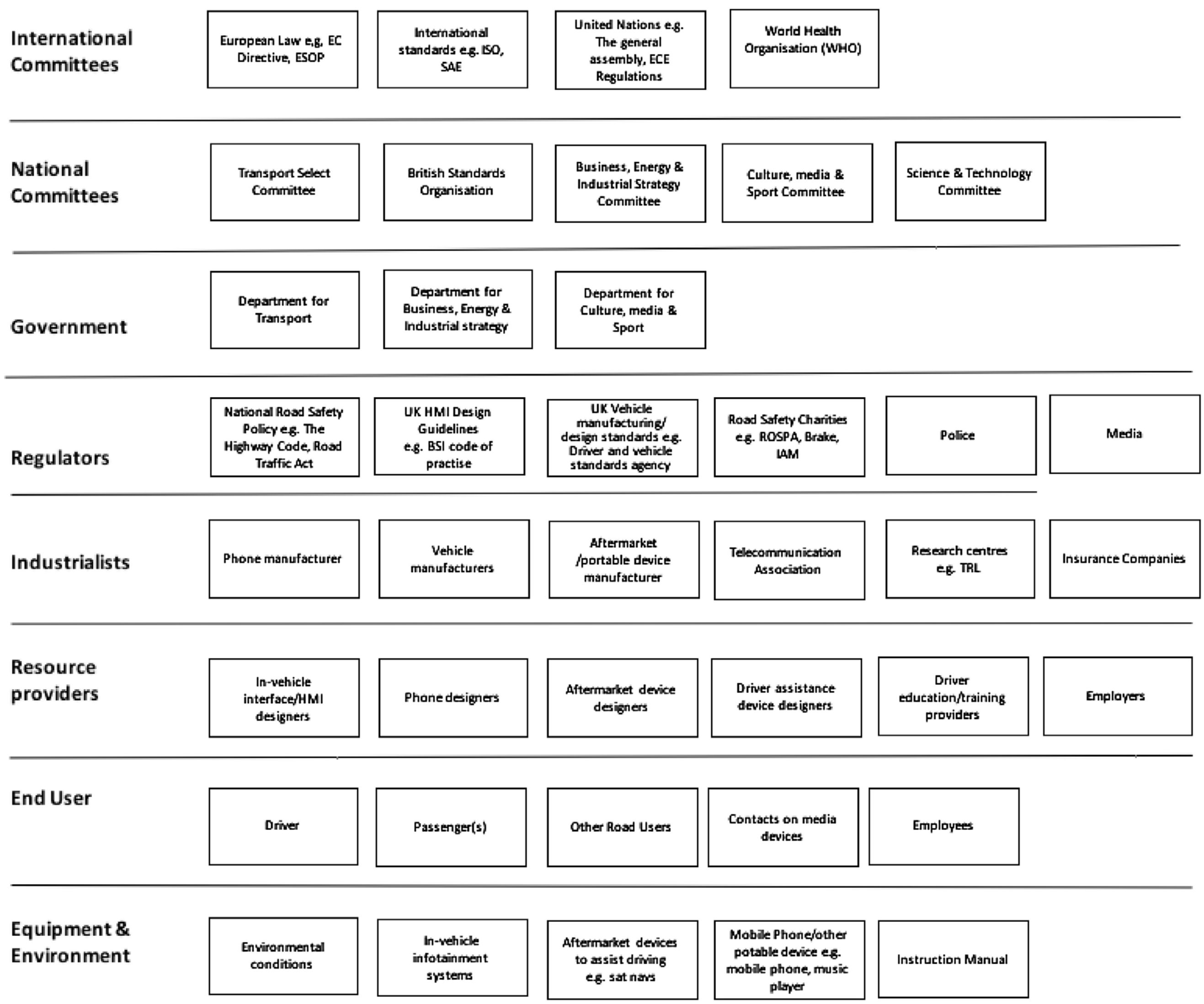

Fig. 2. Actor map containing all actors relevant to the use of in-vehicle technology by drivers.

if they decide to use hand-held phones while driving. Although there are issues proving that drivers are on their phones at the time of incident and often drivers believe that they can get away with using their phone without getting caught (Young and Lenné, 2010). Indeed, without patrolling the roads on the lookout for hand-held phone users the police have a difficult job in enforcing the laws (C6). Furthermore, phone companies still permit phones to be used inside vehicles and therefore enable them to be in conflict with the driving task (C1). Stopping the user from engaging with their device is obviously not the desired practise that mobile phone companies want to employ. Yet, their inclusion in the Accimap in Fig. 3 shows that they have some responsibility for distraction incidents related to hand-held phone use. There are some applications available for smart phones which can limit the usability of the phone while driving and monitor performance to increase safety, but the uptake of these applications is a complex issue (Kervick et al., 2015). The phone company is thus handing over responsibility to the driver, allowing interaction to be determined by the situational and motivational factors of the end-user as they prioritise their goals. Yet, preventing the responsibility from reaching the end-user would stop other factors from influencing the use of the phone while driving. Phone companies are therefore shown not to support Goal Conflict in Fig. 3 (C1). The role passes to driver education providers to manage the priorities of the driver and enforce legislation on the dangers associated with using phones while driving at the training stage (M6). Yet this is not enforced after training is completed and drivers have receive their license. Another management tool recently developed is driver assistance features, such as advanced warning systems and hazard detection functionalities which aim to enhance the drivers' safety and add an additional line of defence to alert the drivers' attention back to the road when they may be distracted (M5). Yet these systems may disturb the driver' risk perception (EU6) (Robert and Hockey, 1997). Instead of enhancing the drivers' safety, warning systems can enhance the drivers' perception of safety leading them to feel protected and therefore increasing the potential to engage in riskier behaviours (Dulisse, 1997). Thus the driver is ultimately left to manage the risks placed in their environment when they are poorly advised on the actual scale of the risks.

Nonetheless when drivers are given the responsibility to manage their own interactions with their phones while driving there is a high level of responsibility that the socio-technical system is placing on the driver. The decision to engage is hard to control without preventing it from occurring at higher levels. The priority that the driver assigns the phone call is also subject to a number of factors which determine the drivers' motivation to engage (EU4). The

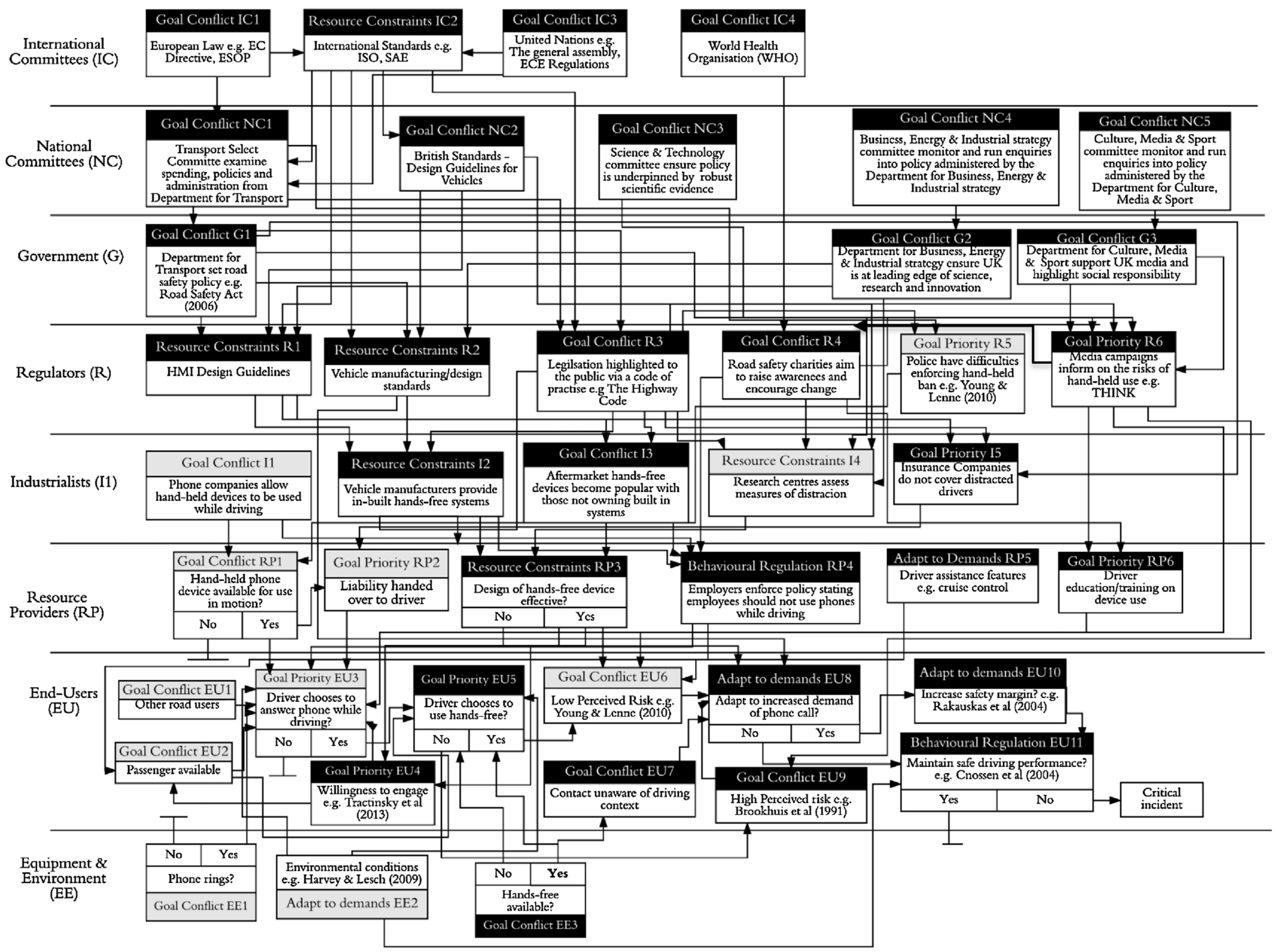

Fig. 3. Accimap of phone use.

unpredictability of this decision means that it is a vulnerable aspect of the system, and is highlighted grey. The presence of other road users in the system and passengers, actors found to influence the decision, are equally random (EU1 & EU2). Prohibiting phones from vehicles would eliminate this variability and facilitate goal prioritisation away from distracting activities. Instead the system is left vulnerable to the interactions of the end users and their interactions within their environment (EE2).

For the most part, Fig. 3 highlights that legislation at the top level of the system defining the ban on hand-held phones is effective in motivating the other levels of the system to provide support against distraction from mobile phone devices. However, caution is needed to prevent drivers from being directed towards alternatives that are not as safe as them may be perceived, such as hands-free devices.

3.2. Accimap of other technology use

Fig. 4 includes significantly more grey boxes across all levels of the system than the Accimap corresponding to phone use (Fig. 3), inferring that less of the PARRC factors are deemed to be supported by the actors under this legislation. This includes elements at the very top of the system, the international committees and regulatory bodies. Unlike Fig. 3, where the international laws highlight the dangers of phone use, the suggestions made for other technologies are less conclusive (IC1-4). Although they are aware of the potential for distraction from a range of technologies, quite how they may conflict with the driving task is less well defined. International standards apply criteria to in-vehicle system design (e.g. SAE recommended practice J2365, Society of Automotive Engineers, 2002). This feeds down through the national committees to the government who state legislation on devices that impact the ability to control the vehicle, proposing drivers must be "*in a position which does not give proper control or a full view of the road and traffic ahead*" (Road Traffic Act, 1988; section 2, 41D) (NC1 & G1). Yet they are less specific about how to avoid distraction and exactly what proper control means. As evident in Fig. 4, there is a clear lack of awareness of the type of conflicting goals that technologies pose to drivers' attention towards the road. This is embodied at the regulatory level, with the highway code stating less clear information on how to avoid distraction from in-vehicle technology (The Highway Code) (R3). Some regulation is evident, road safety charities aim to target all aspects of safety and therefore pay attention to the use of other devices behind the wheel, providing leaflets and information on their distractive effect (R4). Yet these are only available to those seeking to look for advice and are notably less widely available than those corresponding to phone use.

The resource constraints of the driver are accounted for in the system surrounding in-vehicle technology. As with phone use, research into the effects of driving with a secondary task has shown the drivers attentional capacity in addition to the driving task (C7) (see Young et al., 2007). This informs the guidelines put in place for HMI designers and vehicle manufacturers to follow when design-

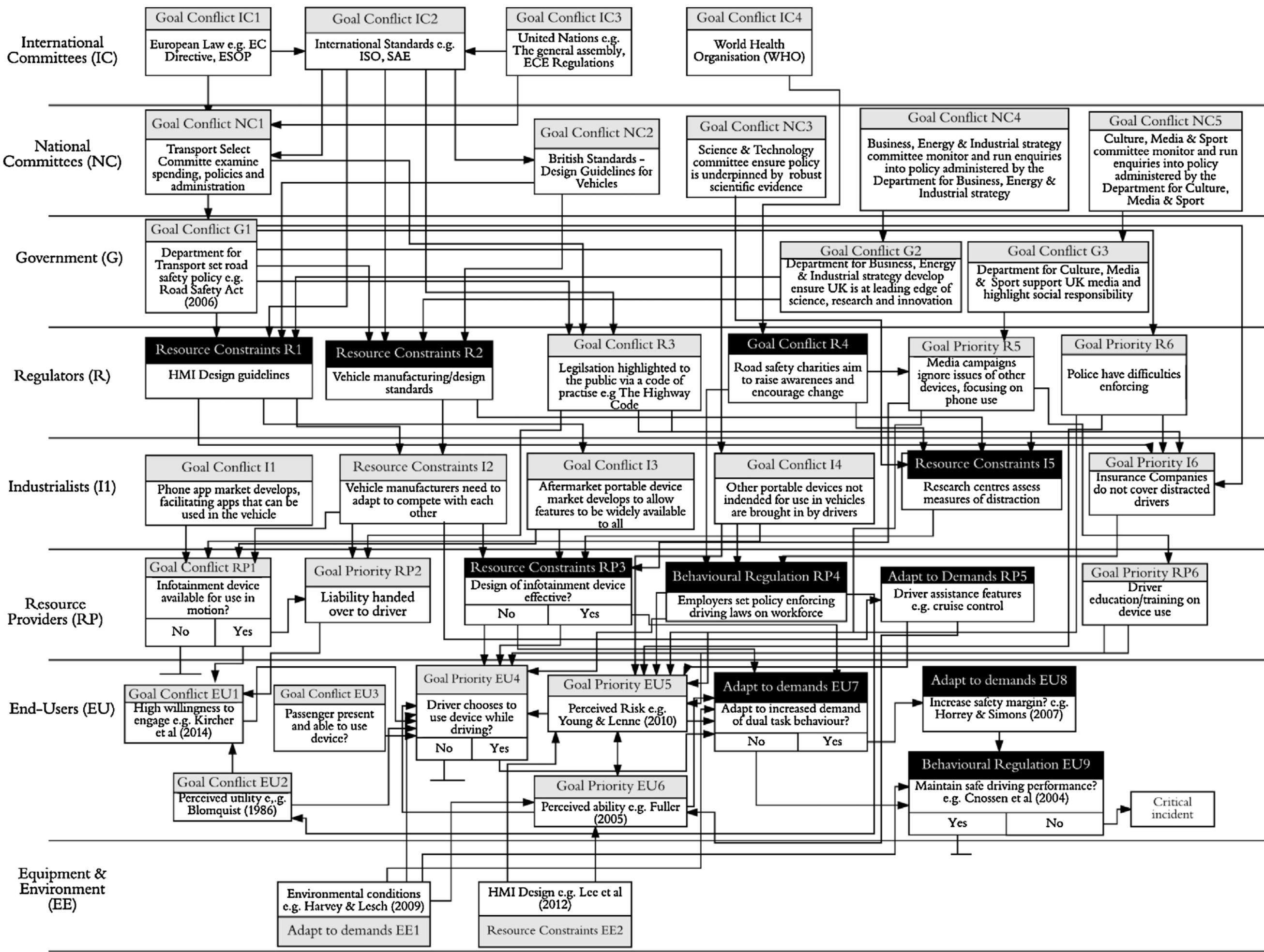

Fig. 4. Accimap of other in-vehicle technology use.

ing driver interfaces (R1 & R2), in line with the international and national standards (IC2 & NC2). Yet, as more companies begin to enter into the in-vehicle technology domain the exact resources that are constraining the drivers' attention are less well known (C1-4). The need to compete and remain profitable means that vehicle and device companies need to offer drivers an enhanced driving experience, offering an array of equipment that is increasingly in demand by drivers who are more reliant upon technology throughout everyday life (Walker et al., 2001). For example, there has been a recent shift towards wearable technologies, such as glasses and watches that link with smart phones, giving another information outlet. These devices may never have been intended for use in the vehicle but their use by drivers needs to be considered. In line with Rasmussen's RMF (1997), legislation at the top level must be aware of these developments in the equipment and 'end users' expectations at the bottom or the framework, in order to adequately and safely manage driver distraction. This propagation through the system has failed in recent years, the technological advancement at the bottom levels is not yet widely accounted for in policies or design standards. Although research has been conducted into the potential effects of devices such as google glasses on driving performance (Sawyer et al., 2014), the disadvantage of distraction from these devices has yet to outweigh the potential benefits they could have in terms of monitoring the driver, providing corrective feedback and reducing load in multitasking (Sawyer et al., 2014; He et al., 2015). It's thought that more thorough testing to understand the useability of all functioning of these devices is required before policy can be set. Yet, without a definition of distraction or proper control, evidence against the use of certain devices is hard to discern from research (Regan et al., 2011). Thus, the effect that new technologies may have when used by drivers is not considered before their release. This means that legislation has to play catch up, leaving road users potentially at risk until the safety implications are realised. This was an issue that was initially found with mobile phones.

As with hands-free devices other technologies must abide by the same universal and national HMI guidelines, to ensure they are fit for use on the road, (IC2 & R1). The design of the device and awareness of risks feeds down in a similar way to phone use. Yet, risk perception of the driver is less well informed by media campaigns as they tend to focus only on the fatal four behaviours as defined by the Transport Select Committee (2016), of which mobile phone use is featured (alongside not wearing a seat belt, speeding and drink/drug driving), while other technologies are overlooked (C5). As all other devices are legal they are likely to be thought of as less risky (e.g. Patel et al., 2008), in the same way as hands-free is thought to be of low risk as it too is permitted in vehicles (Young and Lenné, 2010) (EU5). Drivers tend to have a high willingness to engage with these devices and perceive them as assisting their driving performance and overall experience, in line with manufacturers publicity. For example, satellite navigation systems, whether built-in or an aftermarket device, are also now commonly used by drivers who have begun to rely on them, their assistance with the driving task increases their utility and reduces the perception that

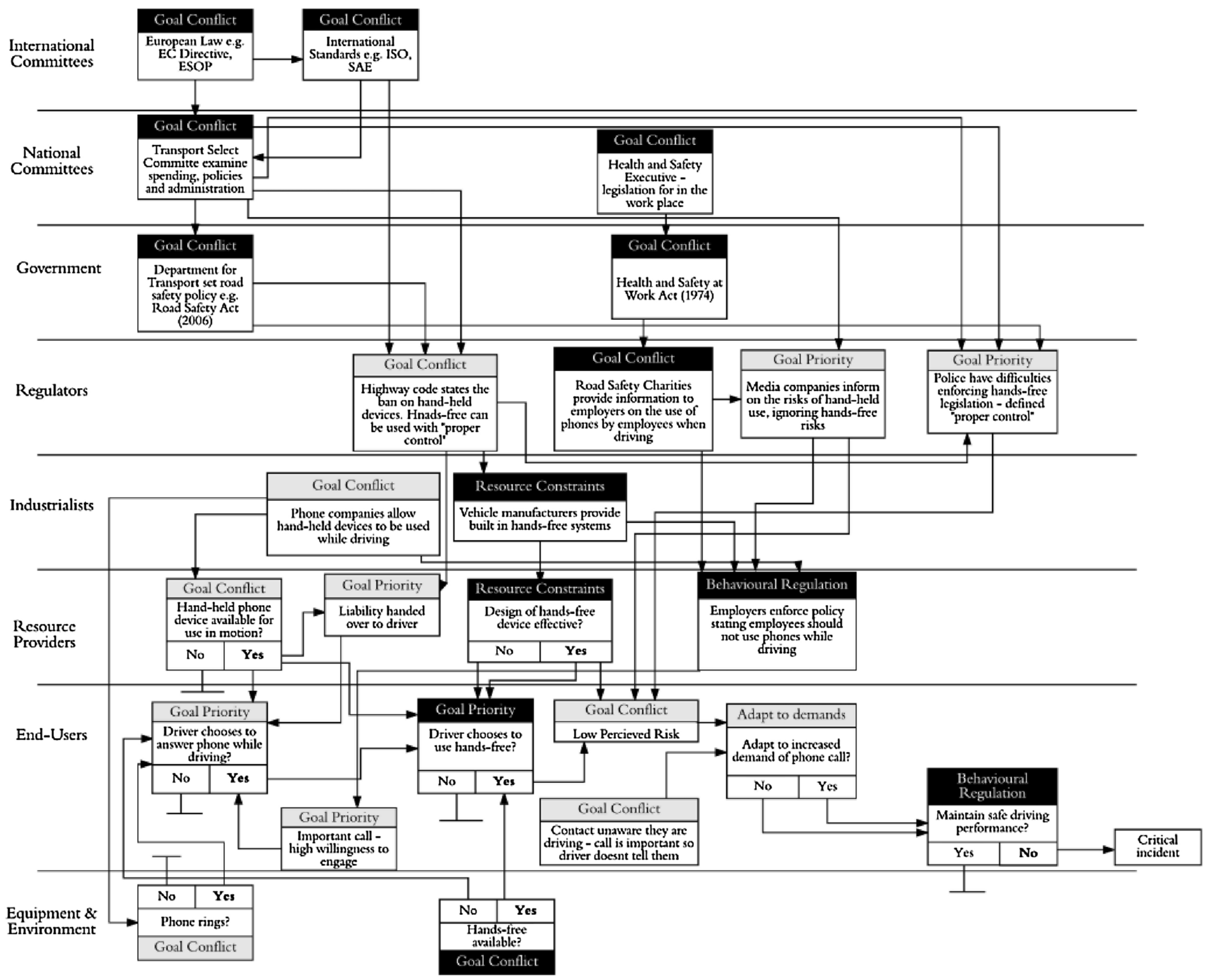

Fig. 5. Accimap depicting the drivers work mobile ringing when the vehicle is in motion. Bold type suggests the decisions made by driver in the scenario.

they may actually risk safe performance (Blomquist, 1986). As in Fig. 3 with phone use, Fig. 4 suggests that the perception of risk and the decision to engage with the device alters the adaption of driving performance and ultimately the maintenance of safe driving performance (EU5, EU6).

The ambiguity in legislation on what does and does not conflict with the driving task is exploited with multiple devices, being brought into the vehicle (built in and nomadic). Although the majority of these devices align with the HMI guidelines, the ambiguous information regarding the terms of use while driving means that the driver is left unclear on the priorities they should make when engaging with the device. Manufacturers provide instruction manuals on best practise and guidelines on appropriate use to remove themselves from a position of liability, but often these are not read or are easily ignored by the end-user (Mehlenbacher et al., 2002). This is an issue as the Accimap shows how the driver is left widely responsible for the actions of the system. The high willingness to engage and the potential utility of technology is not balanced with knowledge of their distractive effects (EU1). Often the utility and benefits associated with engagement overshadow the perceived safety impact (e.g. Kircher et al., 2011). The Accimap can therefore be used to suggest that actors at the higher levels of the socio-technical system are not doing enough to direct the end-user on the goals that can conflict with the driving task and how to prioritise them. As the law directly relates to the use of the device in vehicles, it is the driver caught using it that is held responsible rather than those who permitted the devices to be brought into conflict with the driving task in the first instance.

3.3. *Comparison between mobile phone use accimap and other technology use accimap*

The Accimap analysis allows legislation on phone use and other technology use while driving to be compared on their efficacy in managing distractions. Table 2 and Fig. 7 highlight the number of distraction mechanisms that are supported and un-supported within the Accimaps (Figs. 3 and 4).

A chi-squared analysis (Table 3) revealed that phone Accimap and other technology Accimap were significantly different in the number of support and unsupported PARRC factors $\chi^2(1)=21.02$, $p<0.01$.

Table 2 shows a notable contrast is the goal conflict factor between the two Accimaps, with only one element found to support the system in mitigating distraction from goal conflict between the driving task and other technology. Furthermore, the need to prioritise goals to prevent distraction from other technology is not

Table 2
Frequency table of supported and un-supported PARRC mechanisms across the phone use and other technology use Accimap.

PARRC Factors	Phone Use Accimap		Other Technology Use Accimap	
	Supported	Un-supported	Supported	Un-supported
Goal Conflict	18	6	1	20
Goal Priority	5	3	0	8
Resource Constraints	4	1	4	2
Adapt to Demands	3	1	3	1
Behavioural Regulation	2	0	2	0
Total	32	11	10	31

Table 3
Contingency table showing the observed totals, expected totals and χ^2 statistics.

	Supported		Unsupported				
	Total	Expected total	χ^2	Total	Expected Total	χ^2	*Marginal Row Totals*
Phone	32	21.5	5.13	11	21.5	5.13	43
Other	10	20.5	5.38	31	20.5	5.38	41
Totals	42	42	10.51	42	42	10.51	84 (Grand Total)

captured by any element in the other technology Accimap. Where goal conflict and goal priority are supported it suggests that legislation is giving clear direction on how devices must be managed when driving such that their use does not conflict with the primary driving task (Parnell et al., 2016). The specific ban on hand-held devices distinctly implies the line between appropriate and inappropriate use of the device. Using the phone when driving will lead to the system migrating across the line of appropriate behaviour, inducing a risk to safety (Rasmussen, 1997). This line is less clear and more subjective within legislation regarding other technologies, for both drivers and law enforcers. As in previous research (e.g. Young and Salmon, 2015), it is identified that it is often left to the driver to decide how to behave appropriately. Legislation can therefore be creating a false notion of safety by allowing some devices over others, emphasising the risks of hand-held phones and prohibiting them from vehicles may lead drivers to think that other devices are comparatively less risky if they are not given the same treatment. The ban on hand-held phones may therefore be creating the conditions for distraction from other in-vehicle technologies to emerge from the system. Drivers often overestimate their performance and underestimate risks on the road (Wogalter and Mayhorn, 2005; Horrey et al., 2008), their ability to abide by these subjective laws is therefore called into question.

3.4. Application to specific events

Case study examples are used frequently within human factors research in order to relate theoretical models and psychological factors to the in-depth analysis of naturalistic behaviour. This has allowed further insights into behaviour within the aviation (Plant and Stanton, 2012), rail (Stanton and Walker, 2011) and road transport domain (Parnell et al., 2016). The Accimap methodology is ordinarily applied to single events in order to assess the systems elements that contribute to the event outcome, which Hancock et al. (2009) claim allows for deeper insights when studying human–machine interactions. To further highlight the differences between legislation on phone use and other devices, application of the Accimaps to individual naturalistic scenarios were explored

Scenario 1: A delivery drivers mobile phone rings while they are driving, the display on the phone informs them that it is their manager calling and informing them it is an important call to take.

The safest option in this scenario is not to answer the phone. Indeed, according to the health and safety at work act, employers must inform anyone driving for work purposes not to use their phone while driving (Health and Safety at Work etc. Act, 1974). This should include targeting those making the phone call, knowing there is a likelihood that the person they are trying to contact is driving. Furthermore, employees should be made aware that hands-free devices also have the potential to distract, in line with the governments guidelines. However, as they are not banned from use in vehicles they are seen as an alternative means through which to communicate with workers while driving. The driver in this scenario is highly motivated to answer, as more people drive for work the motivation to remain productive while travelling is high, this is especially true of those in the sales industry (Eost and Galer Flyte, 1998). It is in the company's interest to increase productivity by allowing the driver to communicate when driving and therefore hands-free kits are useful to them as they do not require breaking the law. As long as warnings to employees are given the responsibility is passed on. Fig. 5 shows the employee is permitted to enhance their efficiency by using their phone in hands-free mode while driving, when they receive the call from their manager they are therefore able to prioritise this call. As there may be consequences for not answering their managers call, the driver is highly motivated to respond. The drivers' ability to adapt to the increased demand they are subjected to when engaging with the phone task will determine their ability to maintain safe driving performance. Yet, as they are permitted to use the hands-free device they have a low perception of the risks involved. They are also motivated to engage with their manager so cannot adapt the phone conversation and must adapt their driving behaviour to account for their reduced ability to perceive the environment (e.g. Alm and Nilsson, 1995). Here it can be said that the pressures placed on the employee to increase their efficiency while driving at work force the system into this position of unsafe practise. The systems behaviour pushes it closer to a point at which it is forced across the line of appropriate behaviour (Rasmussen, 1997).

Employers have a responsibility for employees' health and safety while at work and thus risks should be kept to a minimum. While it may go against the productivity targets of an organisation, safety of personnel should be paramount. To prevent actors at the end-user stage from being required to make decisions on engagement, avoiding the use of work mobiles in vehicles by employers including hands-free use would be the safest option. An example counter measure to this would be the use of applications that block out phone calls when it is detected that the phone is in a moving vehicle, or the application of "drive" settings built into the phone. Expectations of the employer and the pressures imposed on staff need to change.

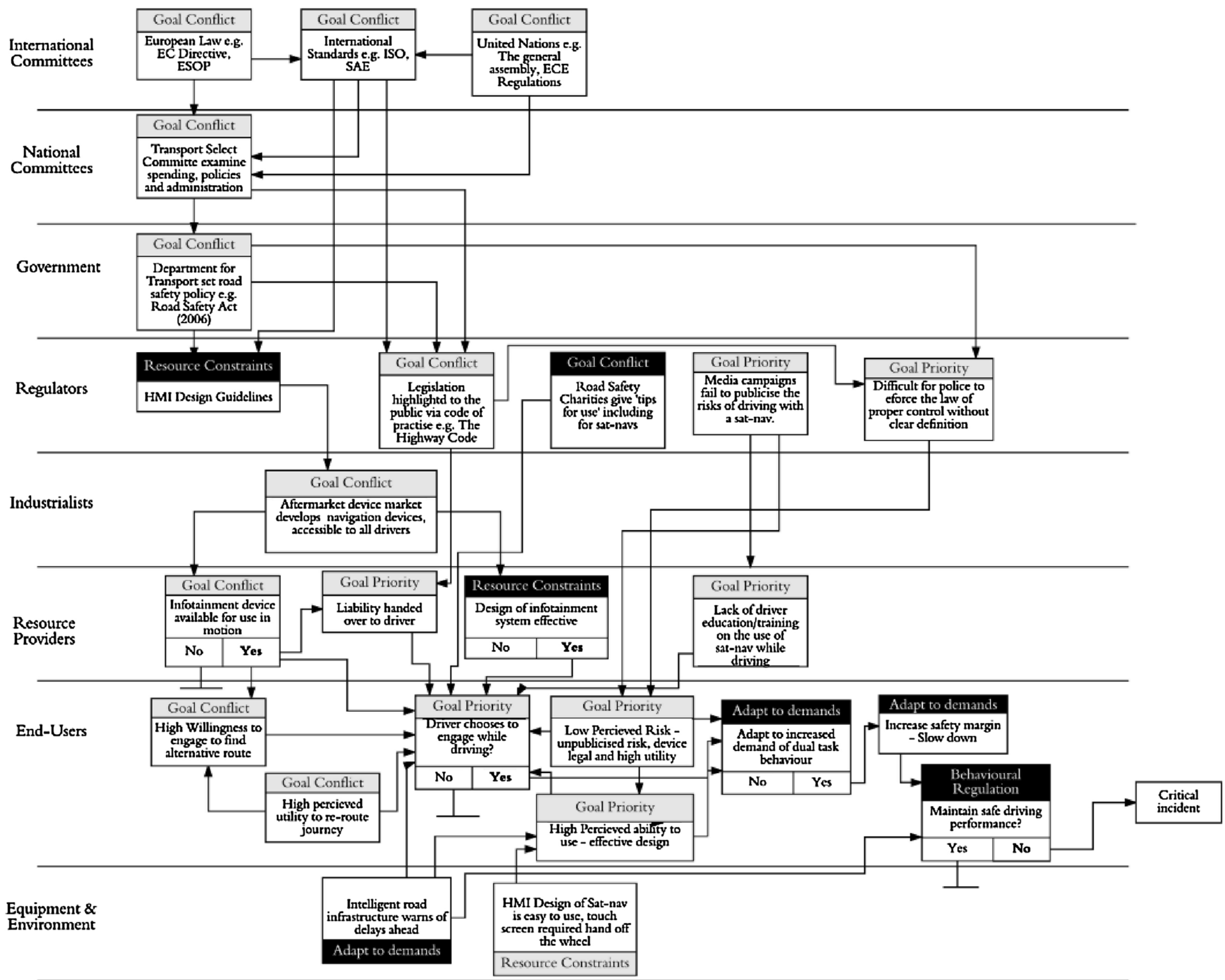

Fig. 6. Accimap depicting the engagement with a satellite navigation device when the driver realises the route ahead is blocked and they need to redirect. Bold type suggests the decisions made by driver in the scenario.

Scenario 2: A driver is using a sat-nav to direct them to their destination when they are informed, by an intelligent road sign, that there is heavy traffic up ahead. They therefore wish to change their route to avoid the traffic. This requires interacting with the sat-nav using its touch screen interface

The sat-nav design meets all regulations set by higher level elements. It warns the driver before they enter the original destination at the start of their journey that the device is not permitted for use when driving but it does not physically stop them from doing so, passing on the responsibility of any incident caused by engagement when driving to the driver. The touch screen interface requires the driver to take their hands off the wheel and their eyes away from the road scene. Yet, it is highly useful in allowing the driver to get to their destination. Hence there is a high willingness to engage coupled with a low perception of risks, as shown in Fig. 6. As the driver utilises the available technologies to prevent them suffering traffic delays, they progress the performance of the system towards an increased risk of incident. Although there is no law to state precisely when their behaviour is unacceptable, taking the eyes and hands away from the driving task greatly increases the risk of incident (e.g. Parnell et al., 2016). The warning upon start-up of the device is easily ignored when the motivation to interact with the sat-nav is high. The driver is effectively encouraged to tests the boundaries to determine how they will perform when using the device while driving as the capacity of the driver to accurately perceive the appropriateness of their behaviour is impeded.

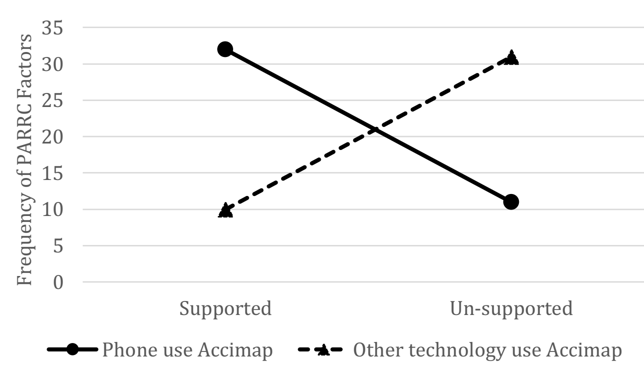

Fig. 7. Graph showing the difference in the frequency of supported and unsupported PARRC factors in the Phone use Accimap compared to the other technology use Accimap.

4. General discussion

Application of the RMF (Rasmussen, 1997) to legislation determining the use of in-vehicle technology by drivers has employed the Accimap methodology to graphically represent the socio-technical system and determine how distraction may be an emergent behaviour of the system as a whole. Predetermined mechanisms of distraction, relating to systems failure in in-vehicle technology use were utilised as taxonomic references from which to categorise normal behaviour across multiple events. These mechanisms were obtained from the PARRC model of distraction (Parnell et al., 2016). This overcame previously cited limitations of Accimaps which stated that they were not generalizable across multiple events, supporting recent research by Salmon et al. (In Press) and Trotter et al. (2014) in providing evidence to counter this limitation. This has enabled, for the first time, an investigation into the impact of UK laws on the distractive potential for in-vehicle technologies within a wider socio-technical system perspective. Although the analysis in this paper focuses primarily on UK legislation, most other countries consider controlling the use of hand-held phones to be a priority in distraction legislation, with less specific guidance given to the range of other technologies not found in vehicles, making the findings widely applicable.

Accident causation is now widely considered to be a consequence of the interrelationships within socio-technical systems (Larsson et al., 2010; Leveson, 2011; Salmon et al., 2012a; Lansdown et al., 2015). The ability to infer causation therefore requires insight into the complexity of this system, a feature which accident causation models such as STAMP, HFACS and Accimaps are able to tap into (Salmon et al., 2011). Much research on distraction from in-vehicle technology to date has utilised simulation studies (e.g. Alm and Nilsson, 1995; Jamson et al., 2004; Beede and Kass, 2006; Lee et al., 2001) which allow the potential distractive effects of new technologies to be assessed without the real-life risks which may be associated with their use. Yet, as the true risk cannot be simulated, the validity of the findings are limited (Lee et al., 2001). On-road studies, by contrast, do offer real-life risk perception, but the safety of the driver and those on the road is of key ethical concern. The manipulations available in on-road road studies are therefore more limited than those available in a driving simulator laboratory. Some studies have utilised on-road studies to assess distraction, (e.g. Recarte and Nunes, 2000; Harbluk et al., 2002; Lerner et al., 2008). However, simulator and on-road studies assess the causal links between measures of driver behaviour in the driving task and their performance in secondary tasks. This limits the ability to assess the impact of wider systems factors on the emergence of incidents.

Utilisation of Rasmussen's RMF (1997) and the Accimap approach has allowed legislation on in-vehicle technology use to be assessed from a systems approach, identifying the role of all relevant systemic elements. A complex combination of factors involved in the development of incidents caused by technological distractions have been highlighted, outside of those immediately involved in the accident; notoriously the driver (Tingvall and Haworth, 2000; Larsson et al., 2010). Furthermore, the location of these consequential elements within the socio-technical system can be located in order to be targeted by distraction countermeasures (see Table 4). Taking a higher-level approach to assessing accident causation is important as it allows the source of an accident within the higher levels to be identified and targeted with higher level countermea-

Table 4
Recommendations across levels of the RMF hierarchy in line with the Accimap analysis conducted.

Accimap Hierarchical Level	**Recommendations**
International Committees National Committees Government	1. Provide clearly worded legislation on avoiding driver distraction that relates to the whole system – not just the driver. This would require clearly defining driver distraction and making all elements aware of their involvement in its emergence. Utilising Lee et al's (2008) definition, all device developers that provide a competing activity that does not enhance the drivers' safety should be targeted. This includes telecommunication providers, nomadic device designers as well as those creating the image that is provided in the media on the engagement with these devices, to highlight the message. 2. Clearly outline what 'proper control' of the vehicle refers to.
Regulators	3. Ensure regulators set out clear guidelines to transport companies that states that they should have a safety management system set up that includes a systematic approach to distraction issues relatingto their operations. 4. Outline what resources may be constrained by devices and how this may implicate the driving task.
Industrialists	5. Thorough testing of devices by drivers should be conducted before their widespread use to determine how they may influence attention towards the road. This should highlight all of the potential risks related to the use of the device. This can then facilitate exploration of systemic actions to minimise any uncovered risks. 6. Enforcement needs to effectively back up the legislation. Policing all drivers is not possible, monitoring of other system factors at an early stage is required such as device manufacturers, phone companies and employers. 7. Research is required to understand exactly what driving, contextual and situational conditions drivers are able to engage with devices. This is likely to differ between devices depending on their resource demand and relevance to the driving task.
Resource Providers	8. Companies that contribute to the development of technology used within the vehicle e.g. phone designer, navigation system designers, in-vehicle HMI developers, should not encourage temptation within the driver to use devices while driving. Legislation should place ownership of incidents on manufacturers who do not limit the use of distracting tasks while driving through freeze-out mechanisms, limited functioning or voice activated alternatives. 9. Preventing engagement with potentially distracting devices at inadequate times, as suggested through research in the level above, should be upheld by those implementing devices for use in the vehicle.
End-User	10. The end-users need to fully realise the risks of engaging with devices and how it may impact the driving task and their ability to perform the two tasks concurrently. The same level of risk should be attributed to distracted driving as drink driving and speeding behaviour, making it a socially unacceptable behaviour. Other elements such as the media, education and road safety charities can work to enforce this attitude change at the end user stage. 11. The high willingness to engage with devices needs to be offset by the potentially distracting effects of the device to make dangerous tasks less desirable to use when driving.
Equipment and Environment	12. The fast pace of technological change which is causing novel technologies to enter vehicles needs to be monitored. This means that the activities that are conflicting with the driving task are understood by other elements in the system such as the police who should look to enforce the law on new devices, media and road safety charities who should publicise the risks of the technologies and the standards and guideline which may need to be updated. 13. The conditions in the environment which impact the driver ability to engage with technological devices need to be recognised and the drivers' ability to interact with them at these points limited.

sures for widespread change (Branford et al., 2009). This aims to move away from countermeasures that solely focus directly, or indirectly, on targeting the driver. Here the Accimap methodology has been expanded upon to allow it to classify the actions of elements to failure mechanisms, specific to the domain rather than generalised taxonomies which feature in other systemic accident causation methods, including STAMP and HFACS.

Previous research claims that legislation on distraction has focused too heavily on the role of the driver, while ignoring the responsibility of the wider road transport system (Young and Salmon, 2015). The outcome of this analysis has enabled the identification of thirteen possible recommendations which can be made to the socio-technical system to target driver distraction from technological devices. These recommendations, stated in Table 4, go beyond the current methods to target drivers with increased consequences for engaging (e.g. DfT, 2016), or that indirectly point to the driver as the cause of error, to target the root cause of technological distractions.

4.1. Limitations and future research

The Accimap analysis does not include public opinion on technology use. Rasmussen's Framework (1997) states that government policies should be informed by the members of the public, the end-users, who must abide them. It is important that those who must abide by the laws accept them, and those regulating them. Analysis into the opinions of drivers has not been as widely observed as quantitative measures of performance, yet qualitative analysis is important to consider (Young and Lenné, 2010). Some attempts to understand drivers' opinion towards legislation on phone use while driving have been made (e.g. Telemaque, 2015; Drury et al., 2012), and some have asked participants to rank distractive activities in vehicles (Patel et al., 2008; Young and Lenné, 2010). Lerner et al. (2008) were one of the few to include in-vehicle technologies in distracting activities, they conducted focus groups into individuals' motivations and risk perceptions of devices in the USA in 2002. At this time there were no laws against the use of hand-held mobile phones and they found that drivers did not attribute particular risk to engaging with phones while driving. They were also more willing to use phones while driving then navigational devices. This is indicative of the impact that legislation has on risk perceptions of drivers. Young and Lenné (2010) found drivers in Australia, where mobile phones were banned while driving, rated phone tasks to be among the riskiest activities to perform while driving. However, this was not found to correlate to reduced use of mobile phones while driving (Young and Lenné, 2010). Future research should endeavour to further explore the role of driver opinion on the use of in-vehicle technology use and driver distraction to determine how it interacts with legislation and the active decision to be distracted.

5. Conclusion

Rasmussen, (1997: p. 184) stated "*society seeks to control safety through the legal system*", yet this paper has shown the inefficiency of legislation that does not regulate the appropriate actors across the whole road transport system. In doing so, it leaves road users vulnerable. This paper has highlighted the effect that current legislation on in-vehicle technology use while driving has on all of the actors across the road transport system that it relates to. Applying the PARRC factors to the Accimap methodology has allowed a first step, within the road transport domain, in overcoming previous criticisms of Accimap methodology. This hopes to improve the validity of the findings. It has also highlighted the relevant actors which prevent the use of hand-held phones while driving and the comparative lack of clarity in the drivers' decision to engage with other technological devices while driving. Recommendations across each level of the socio-technical system have been proposed, such as a need for more clearly worded legislation that can be easily enforced without subjectivity. These recommendations aim to prevent the responsibility for distraction to lie purely within the driver, while motivating other researchers and practitioners to look for further solutions across the whole system. Further work into the role of public opinion is proposed.

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