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Assisting the update of INDG382: Vehicle technologies

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Executive summary

Background and aims

Driving for work can be risky relative to other driving. The reasons for this appear to be a greater likelihood that work-related driving will occur under conditions of time pressure and is more likely to involve driver distraction and driver fatigue. Recent changes in working patterns, such as the 'gig economy', and changes in the vehicle fleet (e.g. increasing prevalence of delivery vans and two-wheeled vehicles) will likely be introducing variations of these risk factors, and possibly others.

Organisations in the UK are expected to manage work-related road safety (WRRS) in the same way that they manage any other health and safety risk in their business, since health and safety law applies to work activities on the road, including driving. Employers are not always aware of this responsibility, and it can be a neglected part of work health and safety management. Hence the Health and Safety Executive (HSE) and Department for Transport (DfT) issue joint guidance through INDG382 'Driving at work: managing work-related road safety' (https://www.hse.gov.uk/pubns/indg382.pdf). This study gathered insights from current literature and from informed stakeholders that can be used to update INDG382 with regard to vehicle safety technologies. It aimed to address the following research questions:

1. How effective can technology be in improving safety in fleet settings?
2. What features of such systems emerge from the evidence as being important for effectiveness and is there evidence of such systems causing distraction?
3. How does effectiveness vary with fleet types or different high-risk groups of drivers?
4. How can such approaches be built into the 'Plan, Do, Check, Act' (PDCA) approach to identifying, controlling and monitoring work-related road risk?

For the purpose of this project, 'technology' referred to any technology which can (through a plausible mechanism) provide relevant information to the employer on potential / actual safety related events or driver behaviours to enable lessons to be learned and improvements to be considered. Such technologies may include vehicle safety systems, telematics, fatigue or distraction monitors.

Method

The literature review examined the impact of technology that provides leading indicators on work-related road safety, particularly where there is a demonstrated relationship between these indicators and crash risk. Leading indicators are proactive, allowing organisations to monitor potential risk (e.g. monitoring speeding events) whereas lagging indicators are a form of reactive monitoring (e.g. incident reporting). It also considered factors that may influence the effectiveness of telematics, including the features of the technology, indicators chosen, organisational context, feedback methods, and the characteristics of the fleet, drivers and driving context.

The stakeholder consultation involved interviews with 19 people including 8 who represented organisations that had implemented some form of technology-based safety monitoring in their fleet and another 11 stakeholders and experts from organisations such as government, road safety bodies, industry associations, insurers, unions, police and academics. The interviews were conducted by phone in April and May 2020. They were approximately 45 minutes in length.

Results

Technology

There were four categories of vehicle technologies found in the literature that fitted the definition above: telematics systems, Intelligent Speed Assist (ISA), Drowsiness and Distraction Recognition (DDR) systems and collision warning systems. More detail about these systems and how they work is included in the body of the report. Other technologies also have potential, but these had not been evaluated in a work-related driving context.

There has been limited rigorous evaluation of the safety benefits of telematics in a fleet context, and gaps and limitations that were identified 20 years ago remain unaddressed. Six studies published in the last 10 years on telematics in a fleet context generally found reductions in safety-related events such as harsh braking, swerving and speeding. However, only one of these examined effects on involvement in collisions, and a study published in 2000 remains the only properly controlled trial that studied effects on collision involvement. Both studies found approximately 20% reductions in collision involvements following the introduction of telematics monitoring systems. An insurer who had oversight of many fleets concurred that they saw significant reductions in the number and severity of claims when telematics systems were installed.

Most systems monitored indicators such as speed (usually relative to the speed limit) and *g*-force events such as harsh braking or swerving. Systems that had cameras were able to record other safety indicators such as distraction and drowsiness events.

Two of the telematics studies included cameras (both had driver-facing and road-facing cameras). Both studies showed reductions in safety-related events and risky behaviours. However, there was no direct comparison of safety outcomes from systems with cameras versus those without. Consultation participants who had driver-facing cameras were confident that they allowed them to coach and train their drivers better, whereas other stakeholders were concerned about the potential for misuse of cameras (e.g. unrelated surveillance by management).

In summary, telematics systems have significant potential safety benefits, but rigorous published evaluation of safety-based telematics in the fleet context is limited, and gaps and limitations identified over 20 years ago remain unaddressed. There is insufficient data to draw firm conclusions regarding the effectiveness of specific features (including cameras) or indicator thresholds. Organisations should make choices based on their risks and use the PDCA approach to assess whether new systems are having the desired effect.

In addition to studies of telematics-based systems:

- One study of the effects of intelligent speed assist (ISA) in a fleet context found reductions in speeding in high speed zones. There is good evidence for the safety benefits of ISA in private and fleet vehicles.
- A study of a drowsiness monitoring system showed a very promising reduction in drowsiness events. This system used algorithms to detect drowsiness events from the driver’s face and eye movements (rather than a camera recording being triggered by

a *g*-force event). If a serious drowsiness event was detected (e.g. a microsleep), the manager would call the driver and discuss what to do to manage the situation.

Management, leadership and feedback

The literature suggests that feedback which involves coaching (goal setting and feedback) is more effective than in-vehicle alerts alone. This was also the general view of participants in the consultation.

Participants in the consultation stressed the need for strong leadership in introducing safety technologies, including the need to communicate clearly with drivers and ensure they knew what was being implemented, the issue it was aiming to address, and how it would work. This included engaging early with unions and staff associations.

The consultation also highlighted stories of organisations being overwhelmed by data, or experiencing difficulties extracting the information that they needed. This resulted in inefficient use or disuse. Monitoring of driver performance at an individual and group level, aided by the provision of useful data, was seen as important to motivate improvement by most participants, so focused and user-friendly data reporting systems are essential. To manage this, organisations should think carefully about the indicators that will give them the best insights into the risks they are trying to manage and restrict their focus to those.

The frequency of monitoring and length of time that data should be retained depends on business needs, the granularity of the data and its uses. Critical incidents should be analysed with the driver as soon as possible, whereas weekly or monthly analysis is more reasonable for routine reviews aimed at identifying and managing emerging trends.

The consultation also highlighted the need to have well documented policies and procedures for handling the data, including to protect privacy of people in the footage and protect staff from unnecessary exposure to traumatic video material. Again, leadership and monitoring is important in communicating a clear organisational commitment to properly following policies that protect worker safety.

It is recommended that organisations first trial a basic or minimum level of any system that they intend to rollout at one depot or in one team to allow them to evaluate the impact of that minimum level of intervention and address any issues. Then, they can add features after a period if needed, and compare results with the ‘minimum’ case. Ideally, they would collect baseline data before starting to give drivers feedback. This approach could be used if a company was considering adding cameras to a telematics system and wanted to know whether it was worth the investment, for example.

Feasibility of telematics systems in smaller fleets and organisations

Most of the organisations using telematics systems were larger and had complex systems. With the increasing availability of plug-in systems, installing systems in smaller fleets may be more feasible. However, the critical issue is making good use of the data. For organisations with fewer resources, it is important that: systems provide ready to use and interpretable reports and data portals; a validated and manageable set of indicators to choose from; and good guidance and/or support in interpreting outputs and coaching drivers.

At-risk groups

Young and novice drivers have a higher road risk than older, more experienced drivers. One study explored the use of a telematics device with a feedback portal for young drivers. The pilot study was promising but inconclusive. No study was found that directly compared effects of technology between driver groups (e.g. young drivers, older drivers etc.), although this has been shown in non-fleet settings. In principal, telematics could be used to reduce risk for this at-risk cohort when driving for work.

There is a growing fleet of drivers and riders in the gig economy who are predominantly young and potentially being exposed to excessive hours of work. With regard to technology, there is an argument that organisations that employ these drivers and riders should be improving app design to reduce inadvertent incentives to engage in risky driving and riding behaviours such as distracted driving, speeding and drowsy driving. There are also potential opportunities to use such apps to promote safer driving and riding.

Recommendations

The report recommends this addition to the bottom of the current page 4 in INDG382.

> *"The Use of Vehicle Safety Monitoring Technology to Manage Risk*
>
> Vehicle safety monitoring technologies ('telematics') can help you monitor risky driver behaviours (e.g. excessive speed, harsh or erratic driving, distraction and drowsy driving).
>
> Things to consider in choosing a system:
>
> - Outputs from the system need to be clearly related to the risk that is being managed. You should monitor the smallest number of indicators that will enable you to effectively manage your risks. A good minimum list would include speed, harsh braking and acceleration, swerving and cornering.
> - Management and coaching feedback are a critical part of the system. Organisations should not rely solely on in-vehicle feedback. Choose a system that does not give excessive in-vehicle feedback that may be distracting for drivers.
> - Intelligent Speed Assist (ISA) technologies are particularly effective and should be prioritised when choosing a system.
> - Where fatigue is a potential risk within drivers' schedules, drowsiness detection technology (which may require cameras) is likely to be effective, although this should not replace fatigue management polices such as proper shift scheduling.
> - Any system should be easy for drivers and anyone responsible for coaching their driving to use, access data from and interpret.
> - Organisations that contract drivers through a 'gig economy' model should recognise their responsibilities in managing WRRS and ensuring the apps they provide to manage the distribution of work do not create additional risk.
>
> Leadership and management considerations:

- As with any business improvement process it is essential that leaders at board and executive level demonstrate commitment to the desired outcomes. This should include clear communication, and embedding the safety and business outcomes being targeted for improvement from the introduction of telematics systems into individual objectives.
- Any telematics system should be implemented using a Plan, Do, Check, Act approach, supported by clear documented policies and procedures."

1 Introduction

There is evidence that driving for work can be risky, relative to other driving (Broughton, Baughan, Pearce, Smith & Buckle, 2003; Grayson & Helman, 2011). The reasons for this appear to be a greater likelihood that work-related driving will occur under conditions of time pressure and is more likely to involve driver distraction and driver fatigue (Grayson & Helman, 2011). Recent working patterns such as the 'gig economy' and changes in the vehicle fleet (e.g. increasing prevalence of delivery vans and two-wheeled vehicles) will likely be introducing variations of these risk factors, and possibly others (Christie, Ward & Helman, 2017).

Companies in the UK are expected to manage work-related road safety (WRRS) in the same way that they manage any other health and safety risk in their business, since health and safety law applies to work activities on the road, including driving. The Health and Safety Executive (HSE) and Department for Transport (DFT) issue joint guidance to companies through the leaflet INDG382 'Driving at work: managing work-related road safety'[1]. At the time of writing, INDG382 was being updated to make recent evidence and guidance available to those using it, specifically around the use of technology-based approaches to manage and lower risk in work-related driving. The study outlined in this document aimed to gather insight from current literature and from informed stakeholders, and that could be used to update INDG382 in this regard.

The research questions for the work were as follows:

1. How effective can technology be in improving safety in fleet settings?
2. What features of such systems emerge from the evidence as being important for effectiveness and is there evidence of such systems causing distraction?
3. How does effectiveness vary with fleet types or different high-risk groups of drivers?
4. How can such approaches be built into the 'Plan, Do, Check, Act' approach to identifying, controlling and monitoring work-related road risk?

The 'Plan, Do, Check, Act' (PDCA) approach is a model for carrying out continuous change to improve processes and products (ASQ, 2020). It assists with identifying areas of concerns and planning data collection and analysis in order to prioritize and rectify problems (HSE, 2013).

1. **Plan:** Identify organisation goals and develop/review a plan to achieved desired goals. Identify obstacles and how to tackle them. Set clear action plans and measurables.
2. **Do:** Implement the plan developed in Step 1 to test its feasibility and effectiveness. Delegate the work. Take note of problems encountered and how they were dealt with. Collect data.
3. **Check:** Analyse the data collected. Measure how you are performing.
4. **Act:** Review your performance. Identify what was learnt. Decide what works and what needs to be improved. Review the plan and repeat from Step 1.

[1] https://www.hse.gov.uk/pubns/indg382.pdf

This report presents the method and findings of a review of evidence, and from discussions with stakeholders, along with recommendations which can inform the update of INDG382.

2 Overview of vehicle safety technologies

To provide context, this section provides a plain language summary of the new vehicle safety technologies that are most relevant to work-related road safety. The technologies discussed are already available on the market and some are going to become mandatory in new vehicles in the UK in the next two years (for example, intelligent speed assistance (ISA), and drowsiness and distraction recognition (DDR)[2]). It is technically feasible for data relating to activation of technologies such as ISA and DDR to be recorded and fed back to fleet managers. Vehicle telematics systems have been used for several years in fleet settings whilst the other technologies covered will provide immediate safety benefits. It is possible for these to be included in future telematics systems.

2.1.1 Vehicle telematics

The term 'vehicle telematics' is commonly used to refer to technology that sends, receives and stores information relating to vehicles, or their drivers, using telecommunications devices. Vehicle telematics can collect and transmit a range of data including vehicle location, condition and kinematics (which can include indicators of driver performance). They vary greatly in their function, features and sophistication. They may be an integrated part of the vehicle's computer systems, an after-market device that is connected to the vehicle, or as an app on a mobile phone.

Most vehicle safety monitoring technologies can be categorised as 'vehicle telematics' as they involve the transmission of information about how a vehicle is performing and/or being driven. General systems that can monitor safety and other functions are called many things, including (but not limited to) In-Vehicle Monitoring Systems (IVMS) and On-Board Safety Monitoring (OBSM) systems. Some technologies, for example ISA and DDR systems, are special cases of vehicle telematics that target a subset of behaviours or driver states that are significant leading indicators of road risk. These technologies are described in section 2.1.2 and section 2.1.3 below.

Vehicle telematics are widely used in fleet management and logistics in the UK, often for more than one purpose. In 2016, an RAC Business survey reported that around two-thirds of fleets had some form of telematics, and the distribution of business users was spread across industries. Driver training was the second most commonly reported use (54%), with a larger majority using telematics to track vehicle locations (80%). Other business uses included mileage recording, tracking deliveries and monitoring vehicle health (RAC Business, 2016).

[2] A full list of the technologies can be found at: https://ec.europa.eu/docsroom/documents/34588

Telematic devices that are most relevant in the context of the current project are those that influence safety through:

1. Collecting data on a driver or rider's safety-relevant behaviours (e.g. speed, mobile phone use, seatbelt use) in addition to collecting information on safety critical events (e.g. crashes or activation of automated emergency braking systems).
2. Providing real-time feedback. This can be done automatically (e.g. through alerts and warnings) or through providing information that enables managers to provide feedback and coaching. The method of providing feedback has the potential to significantly influence safety outcomes (Horrey, Lesch, Dainoff, Robertson & Noy, 2012).

In 2017, the Future Cities Catapult produced an analysis of the structure of the UK automotive telematics market with a focus on road safety solutions (Griffiths, 2017). They identified that the types of safety-relevant metrics most commonly measured and monitored included:

- journey start and finish times
- vehicle speed
- vehicle location
- acceleration
- braking
- cornering
- seat belt use
- fuel consumption.

More advanced systems integrate video or sensor data to monitor the driver and/or the surrounding traffic environment. These data can be used to monitor indicators of driver states like distraction and fatigue, as well as enabling more detailed analysis of crash causes (Griffiths, 2017).

In addition to standard GPS and accelerometers, some vehicle telematics include event data recorders or journey data recorders.

- ***Event data recorders*** monitor how and where a vehicle is being driven but only record data in response to a safety critical event (such as a crash or a pre-defined dangerous behaviour. This could include harsh acceleration, cornering or braking indicated by exceeding a *g*-force threshold or loss of traction).
- ***Journey data recorders*** continually monitor and record information on how and where the vehicle is being driven. Analysis and feedback are given to the driver and/or a third party (for example, a safety manager).

Finally, some systems alert emergency services of the time and location of crashes, which can reduce the time it takes for medical care to reach road casualties and improve likelihood of survival.

2.1.2 Intelligent speed assistance

There is a large body of research that establishes a clear link between speeding and crash involvement as well as crash severity (Forum, 2018). Intelligent speed assistance (ISA) is a type of advanced driver assistance system (ADAS) that helps drivers to comply with the speed limit. Many new vehicles now integrate basic advisory or supporting ISA into their dashboards and cruise control functions.

There are three broad categories of ISA: Advisory, Supportive and Mandatory.

- ***Advisory*** ISA displays the speed limit and alerts the driver when they exceed it through visual and/or auditory warnings.
- ***Supporting*** (also referred to as ***intervening*** or ***voluntary***) ISA limits the vehicle's speed to the speed limit (or another limit set by the driver), but the driver can over-ride the limiter (e.g. by manually turning the limiter off or applying deliberate and forceful pressure on the accelerator).
- ***Mandatory limiting*** ISA limits the vehicle's speed to the speed limit and cannot be overridden by the driver (e.g. large and heavy vehicles are speed limited in many jurisdictions) (2017).

Some of these systems can collect and transmit data about vehicle speeds back to base. In general, systems that are more automated and intervene to prevent the vehicle from speeding are likely to be more effective but may not be as well accepted by users.

Most fleet telematics systems monitor speed, and some provide speed warnings and/or limit speeds.

2.1.3 Drowsiness and distraction recognition

Drowsiness and distraction recognition systems monitor the driver for signs of drowsiness or distraction and provide a warning to the driver and/or a supervisor. Some systems only detect distraction or drowsiness while others detect both. They differ significantly in function, and their effectiveness is not yet well established) (Seidl M *et al.*, 2017).

Methods that have been used in drowsiness detection include:

- Vehicle-based measures: e.g. deviations in lateral lane position, steering wheel movements, changes in pressure on the accelerator pedal
- Behavioural measures (often facial measures): e.g. yawning, eye closure and blinking and head pose monitored through a camera
- Physiological measures: physiological signals measured by electrocardiogram (ECG), electromyogram (EMG), electrooculogram (EoG) and electroencephalogram (EEG). In recent years, the use of salivary biomarkers have also been explored.

All methods have advantages and disadvantages. Physiological measures and biomarkers are attractive due to their reliability in detecting drowsiness. However, they can be challenging to implement in an occupational setting, often requiring the driver to wear a device that contacts their skin to take measurements.

Physiological measures also cannot be used in isolation to monitor attention on the driving task. This is because, on their own, they cannot identify what is being attended to. Physiological markers of visual attention may be the same when a person is attending visually to the driving task (e.g. driving and reading a sign) or to a different but equally engaging visual task (e.g. reading a message on a phone).

Some researchers consider behavioural measures to be superior to vehicle-based measures because they can detect signs of drowsiness and some forms of distraction before a safety critical event (e.g. a deviation in lateral position) (Sigari, Pourshahabi, Soryani & Fathy, 2014).

Some vehicle safety management systems on the market have integrated DDR functions but this is relatively new technology and the market is still developing.

2.1.4 Automatic emergency braking systems and other forward collision avoidance

Automatic emergency braking (AEB) systems use sensors to track vehicles (and sometimes other objects or road users) ahead and automatically apply the brakes to avoid or reduce the impact of a crash. Manufacturers market AEB using a variety of names. However, they can be classified as follows:

- ***Low speed*** systems: work at low speeds (e.g. in parking scenarios or traffic queues) to prevent or reduce the impact of low speed collisions
- ***High speed*** systems: can scan 100s of metres ahead to detect and brake to prevent or mitigate potential rear-end collisions
- ***Pedestrian*** systems: detect pedestrians and brake to avoid a collision.

Vehicles can have more than one type of emergency braking system. Related technologies include:

- ***Forward collision warning systems*** that detect when the vehicle is approaching another vehicle or object at an angle and speed likely to result in a collision and warns the driver but <u>does not</u> brake automatically. Many new vehicles now have this kind of technology as an option.
- ***Adaptive (or active) cruise control systems*** that detect the distance and speed of vehicles in front and maintain a safe following distance.

2.1.5 Lane keep systems

Lane keep systems help to prevent drivers from leaving their lane and running off the road or into an adjacent or oncoming vehicle. This is particularly helpful in preventing fatigue related crashes. As with AEB, manufacturers use different names for this technology. However, they can generally be classified as follows:

- ***Lane Departure Warning (LDW):*** Drivers get audible and/or visual warnings that their vehicle is approaching or crossing lane markings when the turn signal is not activated.
- ***Lane Keeping Assist (LKA):*** Provides automatic steering and/or braking to keep a vehicle in its travel lane.

- ***Road Departure Assist:*** Provides automatic steering and/or braking to try to keep the vehicle from departing the roadway.
- ***Lane Centring Assist (LCA):*** Provides automatic steering and/or braking to continually centre the vehicle in its lane.

3 Method

The research questions were addressed through two stages:

1. Literature review
2. Stakeholder interviews

Figure 1 illustrates the methods undertaken to complete this report. These steps are described in more detail below.

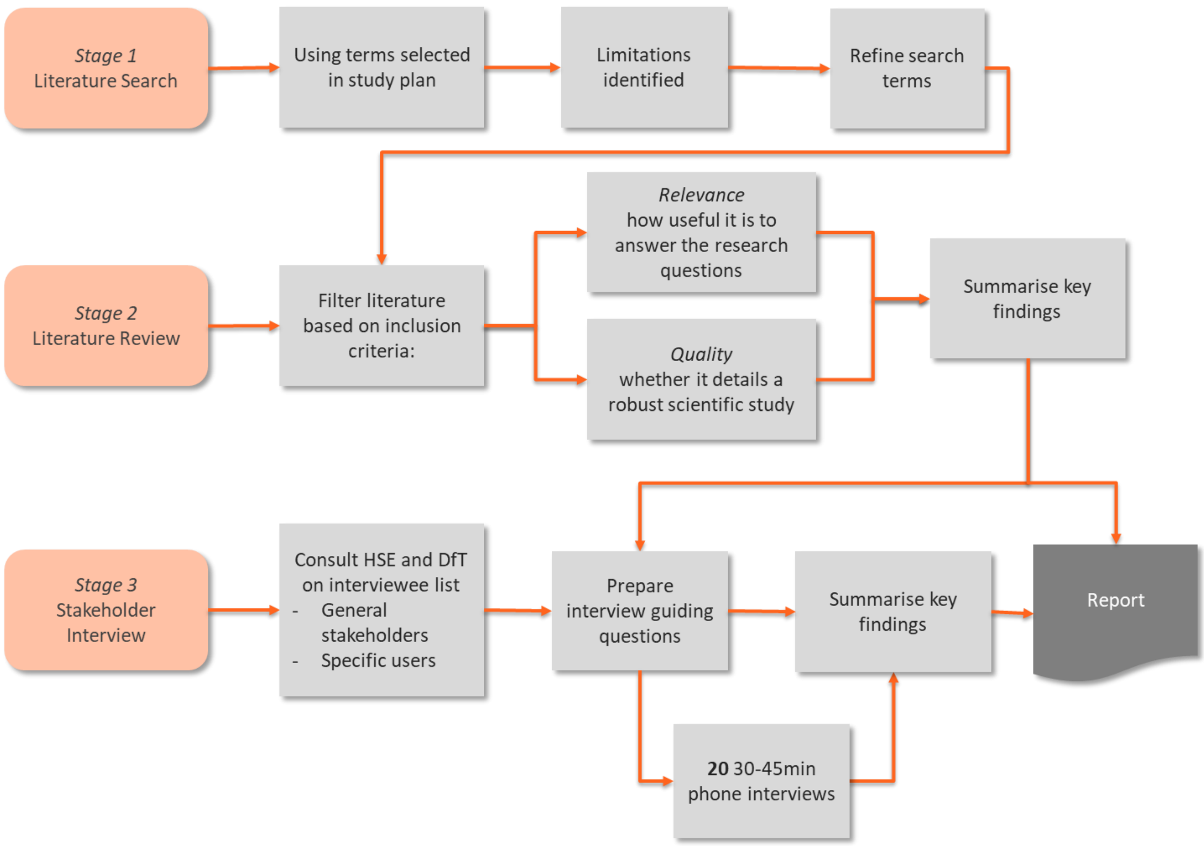

Figure 1: Diagram of the steps involved in completing this report

3.1 Literature review

The literature review aimed to:

- Understand the impact of technology on safety within work-related driving, as measured by leading and lagging indicators
- Understand what specific features of such technology are most effective, or present greater risk through added distraction and how those risks may be mitigated
- Understand what differences may exist between different fleet types and different high-risk driver groups in the levels of effectiveness found.

For the purpose of this project, ‘technology’ refers to any technology which can (through a plausible mechanism) provide a leading indicator to the employer – such as vehicle safety systems, fatigue or distraction monitors.

In the health and safety domain, leading indicators are measures that are predictive of a future injury event. Good leading indicators are accurate predictors of future risk, allowing organisations to monitor risk proactively rather than waiting for incidents to occur. Importantly, they also provide opportunities to intervene to prevent injury. Examples of leading indicators used in vehicle safety monitoring technologies include speed (often speed relative to the speed limit), harsh handling of the vehicle (e.g. sharp braking, acceleration, cornering and swerving) and sometimes fatigue and distraction events such as micro-sleeps or time spent looking away from the road. Lagging indicators are a form of reactive monitoring requiring the reporting and investigation of specific incidents and events. Examples include, periodical measures of collisions and repair costs. Lagging indicators are useful to monitor to validate the reliability of leading indicators and evaluate the effectiveness of interventions.

The initial search criteria restricted the search to literature since 2011. This is because there was a literature review conducted by TRL for the Institution of Occupational Health and Safety on work-related road safety, published in 2011. That review covered what literature existed at the time on the use of IVDR systems to manage WRRS.

TRL has access to a range of databases and sources that were used for undertaking this literature search. The databases that were used allow us to obtain literature both specific to the transport sector (e.g. TRID) as well as other relevant sectors, such as behavioural psychology (e.g. ScienceDirect) and more general sources such as Google Scholar.

The literature review took a systematic approach consisting of three key tasks:

1. Definition of search terms
2. Assessment of quality and relevance
3. In-depth review of full text literature

A detailed description of each of these tasks can be seen in Appendix A and a summary of this process can be seen in Figure 2.

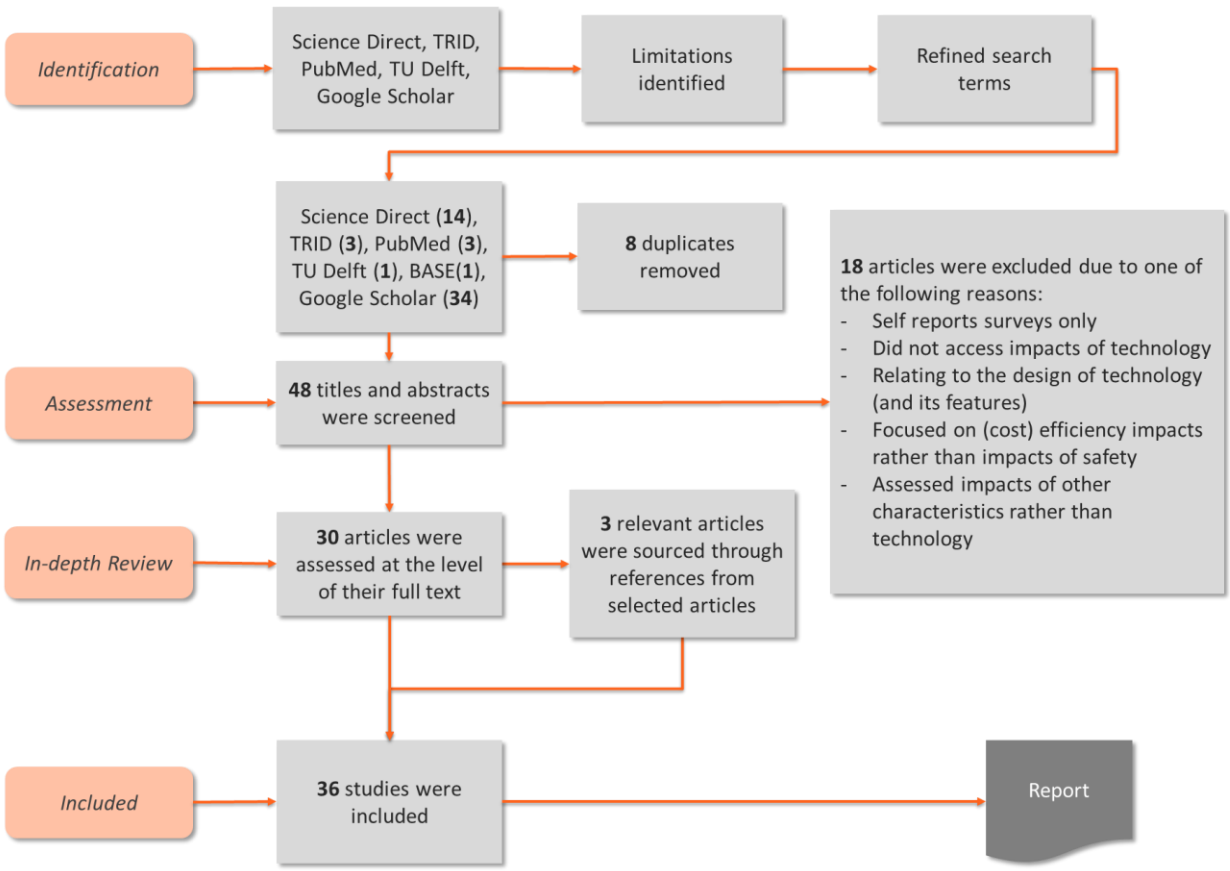

Figure 2: Flowchart illustrating the process of literature identification, assessment, and inclusion for the final review

3.2 Consultation

The second stage involved 19 interviews with stakeholders and representatives from organisations that had implemented telematics systems. A list of potential interviewees was agreed with HSE and DFT. Interviewees were broadly in one of two categories: general ‘stakeholders’ (those with an associated interest in WRRS who held informed opinion helpful to the research) and ‘Fleets’ – organisations who have implemented technology-based solutions and can contribute to answering questions about implementation.

Each interview took around 45 minutes to complete and was conducted over the phone.

The interviews sought to gather:

- Case study examples of organisations that have been successful in implementing monitoring technology, and the associated observed benefits.
- Case study examples of organisations that have failed to successfully implement monitoring technology, and gain insight on the barriers that exist towards that successful implementation.
- Insight as to how monitoring technologies can be built into the ‘Plan, Do, Check, Act’ approach to identifying, controlling and monitoring work-related road safety.

Short topic guides were created to ensure that relevant information was collected from stakeholders and fleets. Questions focused on gathering intelligence on how technology and telematics systems are being integrated into fleet settings, barriers to their implementation, broad lessons learned in implementation, and how such technologies can be successfully integrated into the 'Plan, Do, Check, Act' approach. A charity donation of £25 on behalf of the interviewees was made in return for taking part in the interview. Once the interviews had been completed, the main points were transcribed from the interview recordings. The interview summaries were sent to the relevant participants, to check that they accurately reflected the interviews.

Data gathered from the interviews did not undergo formal qualitative analysis. Rather, a broad set of points were drawn from the interviews in line with the objectives of the interviews.

4 Literature review

4.1 Effectiveness of vehicle safety technologies

This section reports the results of the systematic literature review on the impact of vehicle safety technologies on work-related road risk, as measured by leading and lagging indicators. Leading indicators are proactive, allowing organisations to monitor potential risk (e.g. monitoring speeding events) whereas lagging indicators are a form of reactive monitoring (e.g. incident reporting). Lagging indicators are often used to validate the measurement of leading indicators.

Some of the technologies identified in this review monitored multiple risky driving behaviours. They were referred to by different names, including ‘on-board safety monitoring systems’, ‘in-vehicle data recorders’ (IVDRs), ‘in-vehicle monitoring systems’ (IVMS) and ‘driver monitoring systems’ (DMS). They all have common elements of enabling employers to monitor diverse risky driver behaviours and provide feedback to drivers. The terms are used interchangeably throughout the review, but all refer to general ‘telematics’-based safety monitoring systems of interest in this work.

Literature on telematics systems are discussed in section 4.1.1. Other technologies that are focused on a specific risky driving behaviour (e.g. speeding, drowsiness, distraction) are covered in subsequent sections. Intelligent Speed Assist (ISA) are covered in section 4.1.2 and Drowsiness and Distraction Recognition (DDR) in section 4.1.3.

Factors that influence the effectiveness of vehicle safety technologies is covered in section 4.2.

4.1.1 Telematics systems

We reviewed six studies of multi-functional telematics systems that were published since 2011 (Quayle & Forder, 2008; Hickman & Hanowski, 2011; RoSPA, 2014; Bell, Taylor, Chen, Kirk & Leatherman, 2017; Sullman, 2017; Krum, Hanowski, Miller, Schaudt & Soccolich, 2019). Most of the systems recorded safety events when some pre-set threshold was exceeded. Triggers included *g*-force based events such as harsh acceleration or braking, swerving or aggressive cornering, as well as speeding. More detail on leading indicators in each study is provided in Table 1 at the end of section 4.1 on page 11.

Two of the systems were linked to a driver-facing camera and a forward-facing camera that recorded footage for a set period before and after the event (8 seconds prior and 4 seconds after for the system reported by Hickman and Hanowski; and 15 seconds prior and 15 seconds after for the system reported by Bell *et al.*). Both the systems that included cameras supported the analysis of additional behavioural indicators such as seatbelt use, following distance etc. that were analysed post event (i.e. they did not trigger an event). The footage was saved in a portal that managers accessed to review incidents and coach their drivers.

One small study by the Royal Society for the Prevention of Accidents (RoSPA, 2014) was not a formal evaluation of effectiveness, but is included because it had quite a different approach to the other systems reported here. A ‘black-box’ device was installed in the vehicle that took measurements of the individual's driving every second and calculated a score. The score was based on pace (appropriate speed for the conditions), smoothness (braking and acceleration), calmness (acceleration and cruising speeds) and anticipation (braking patterns). Scores were mapped onto the road network and driving conditions (lighting and weather) were also recorded. Drivers could access their data on a web portal. Over the nine-month period, scores improved for 13 out of 17 drivers who always drove the one vehicle. Regular reminders to review feedback in the online portal were seen as important for the effectiveness of the system.

All the studies examined the effect of a telematics system on *g*-force based and speed-based leading indicators and generally found significant reductions in these events. Only one directly measured effects on crash involvement. Quayle and Forder (2008) observed a 20% reduction in crash rate between the baseline and intervention period. However, the study design was a case-crossover[3], so it was not possible to definitively state whether the reduction in crashes was due to the telematics system or some other change between the baseline and intervention period. Further, no information was provided about the severity or numbers of crashes before or during the intervention, nor what the denominator of the crash rate was, so it was not possible to examine the statistical reliability of the reported reduction.

Hickman and Hanowski (2011), which was one of the studies that included an event-triggered camera recording, reported on reductions in 'safety-related events'. These included collisions (there were five across the study period), as well as *g*-force based events, but also behaviours such as driving unbelted. The study reported reductions in recorded events although these cannot necessarily be interpreted as reliable estimates of reductions in crash risk.

Bell *et al.* (2017) the second system with cameras, found significant reductions in a wide range of leading indicators such as driving un-belted, smoking, hand-held device use while driving, unsafe stopping, and speeding. The study design was robust, but there was no direct examination of the effect on crash involvement.

A previous literature review by Grayson and Helman (2011) was able to cite only one properly controlled study at the time of the review (Wouters & Bos, 2000). Wouters and Bos found a 20% reduction in crashes across seven fleets. This study is now over 20 years old (the trial occurred in 1995). However, it is considered further in section 4.2.3 due to its robustness compared with other studies and the attention paid to differences in fleet characteristics.

Consistent with previous reviews, most of the telematics systems studies reviewed in Table 1 had limitations including:

- lack of published validation of the leading indicators in terms of predicting objective safety outcomes
- lack of transparency around event triggering thresholds
- no evaluation of the effect of the system on objective safety outcomes such as crash involvements

[3] In its simplest form, a case-crossover is a study design in which participants 'cross over' from being controls (not exposed to the intervention) to cases (who are exposed to the intervention). They can be more complicated, involving multiple interventions and time periods, but most we have reported here are simple.

- lack of use of control groups (making it difficult to ascertain that any change in safety outcomes was attributable to the system and not some other change)
- non-random selection of participating drivers (which introduces opportunities for bias, for example, towards more compliant drivers)
- a tendency for participant samples to be homogeneous (similar level of education within the organisation, nearly all male and generally older, particularly for commercial drivers)
- examination of a single device making it difficult to compare which features have a greater impact on driver safety
- very little information about how feedback is provided to drivers and no systematic review of what type of feedback is most effective in producing ongoing safety benefits (although there have now been some studies that have looked at the effect of immediate versus 'off-line' feedback, e.g. (Bell *et al.*, 2017; Sullman, 2017).

There were some notable efforts to address these limitations, for example, Sullman (2017) addressed three of the limitations above in a randomised control trial that compared two types of feedback. This study is considered further in section 4.2.2.2.

4.1.2 Intelligent Speed Assist and speed monitoring

The review identified only one published study that examined intelligent speed assist technologies (ISA) in a work-related context in the last 10 years, and this was a very small study with only seven truck drivers in a case-crossover design with no control (Fitzharris, Stephan, Newstead, Truong, Healy *et al.*, 2011).

A recent literature review on the effectiveness of ISA was identified, and a brief overview was considered worthwhile including here as it provides evidence of a link between speed interventions and crash involvement. Ryan (2019) highlighted that ISA devices that intervened to prevent speeding were more effective in reducing speeding and predicted crashes than ISA devices that simply warned the driver. Additionally, while advisory ISA devices were associated with reduced speeds and improved speed limit compliance in one study with truck drivers, that study found no evidence of the effectiveness of advisory ISA in lower speed zones (Fitzharris *et al.*, 2011).

One study examined the effects of speed monitoring in a small study that used an on-board diagnostic tool to monitor drivers' speeding (without providing any in-vehicle alert) combined with an intervention involving feedback on the driver's speeding events for the preceding week and goal setting for the upcoming week. Seventy-five per cent of participants recorded fewer speeding violations and the average rate of violations reduced from .031 per km to .027 per km. The effects diminished after the feedback sessions stopped (Newnam, Lewis & Warmerdam, 2014).

4.1.3 Drowsiness and distraction recognition

The two telematics systems with cameras mentioned in section 4.1.1 were able to discern distraction and drowsiness events, but only post-event. We identified only one study of a standalone driver fatigue (drowsiness) monitoring system in a work-related driving setting.

The system in this study was rolled out progressively in a freight transport company in Australia between 2011 and 2015. The company ran short-, medium- and long-haul freight. The study started with 16 vehicles at baseline, included 142 in the 1st stage of the intervention and 324 in the 2nd stage, in a case-crossover design. The different numbers of vehicles in each period and the effect of different vehicle types in each period were controlled for statistically (Fitzharris, Liu, Stephens & Lenne, 2017).

The monitoring system incorporated a driver-facing camera. The system analysed a range of movements (including eyelid opening, eyelid shape, pupil size, and head pose) from the video and classified fatigue events (mitigation, drowsiness, or microsleeps). Events were uploaded to a central operations centre where they were vetted by a trained analyst who passed on safety-critical events to the driver's control centre.

At baseline, there were no alarms or feedback. The first stage of the intervention (IM-1) involved alarms only. In the second stage (IM-2) there were alarms plus immediate employer feedback. Fatigue events reduced by 66% with provision of in-cab warnings, and by 95% when real-time direct feedback from company management was provided in addition to in-cab warnings. Both results were statistically significant.

The feedback and results are described in more detail in section 4.2.2.5. Whilst it is highly likely that a reduction in fatigue events such as microsleeps would be associated with a reduction in crash risk, crash involvement was not specifically measured in the study.

There was also a mobile phone blocking technology trial that found significant reductions in self-reported phone use, and positive attitudes towards the technology, despite high levels of unreliability (Ponte, Baldock & Thompson, 2016). These results probably speak more to the influence of the existing safety culture in the organisation than the effectiveness of the technology.

4.1.4 Collision warning systems

There was only one study that directly measured the effects of a collision warning system in a work-related driving context (Krum *et al.*, 2019). It was a simple blind spot object detection and warning system that alerts drivers when an object is in their blind spot using amber LEDs mounted on both wing mirrors. There were 20 truck drivers involved in this case-crossover study. Merger and side swipe safety critical events (including crashes, near-crashes, crash relevant conflicts and unintended lane deviations) per 10,000 miles reduced from 0.64 events to 0.34 events per 10,000 miles respectively, though this was not statistically significant ($p=.08$). Drivers commented on the inaccuracy affecting their confidence in the device. The device accurately detected real objects around 90% of the time; 5% of detections were false-positives and 10% were false-negatives.

Small, Bailey and Lydon (2014) took results from studies of the effectiveness of forward collision warning systems and modelled these in a company fleet context. They predicted 40% reductions in fatal crashes and 50% reductions in injury crashes for vehicles fitted with Forward Collision Avoidance Technology. The study was modelled based on crashes in low-density urban and moderately rural geography in an Australian state. While real-world evidence from fleets is minimal currently, collision warning systems have the potential to have a major impact on rates for certain types of collision (e.g. rear end collisions).

Table 1: Summary of literature on vehicle safety technologies and work-related road safety

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
Telematics systems							
Telematics system (no cameras)	(Wouters & Bos, 2000)	Matched case-control	840 vehicles, including 270 with a simple IVDR installed 7 fleets with different types of vehicles, in different transport sectors etc.	One fleet had a journey data recorder installed Remainder were event data recorders.	No leading indicators were observed as part of the study, although the devices could record them.	Crashes (from insurance records) reduced by 20% overall with variability between fleets.	The features of the devices were not considered a focus of the study and no information is provided. Authors noted sig. differences between fleet types.
Telematics system (with camera)	(Hickman & Hanowski, 2011)	Case-crossover	(Carrier A): 36 from a long-haul carrier in South-eastern US (Carrier B): 42 from a short-haul carrier in North-western US.	*Phase A (Baseline):* 4 weeks, no feedback to drivers, no access to data for managers. *Phase B (Intervention):* 13 weeks, drivers received immediate visual feedback (light) from the telematics device. Managers had access to recorded data and followed a coaching protocol with drivers (when necessary).	Collision and risky driving behaviour (hard brake, collision, distraction, poor awareness, aggressive, risky behaviours (unbelted, following too close, traffic violation, failed to keep an out, poor lane selection, in others blind area))	The mean rate of safety-related events/10,000 miles reduced significantly by 37% and 52.2% at Carriers A and B, respectively from the baseline to the intervention phase.	A combination of video monitoring AND behavioural coaching may be effective at reducing risky driving. The authors argue this may be because feedback and training from managers reinforced safe driving behaviours. Impact of telematics system on safe driving behaviour is limited in several ways in this study. Recommendations made for goal setting for drivers together with

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
				telematics device had two camera views: (1) driver's face view, and (2) forward-facing view.			feedback to reach ideal optimal results.
Telematics system (no cameras)	(Quayle & Forder, 2008)	Case-crossover	250 vehicles fitted with a telematics device. A cross-section of vehicles was selected - those driven by: 'high risk' field-based engineers working in rural areas, some management cars including those driven by the health and safety management team.	The telematics device combines in-vehicle technology with integrated web applications. Immediate feedback is given to the driver using a LED device. Data is also sent to a web server that drivers are encouraged to view weekly to analyse individual reports.	120 driver behaviours including braking, accelerating, lane handling, passing, cornering, swerving, speeding and turning.	1^{st} 3 months – average of 81 unsafe manoeuvres for every 10 hours of driving, reduced to average of 41 unsafe manoeuvres for every 10 hours of driving. The crash rate during the 12 month trial period drop by 20% compared to the 12 month before the trial period. 49 % reduction in vehicle repair costs and 3% reduction in fuel costs. Savings of AUD 830, 000 in costs for bent metal.	Resulted in improved safe driving behaviours', mitigate risk by lowering the number of near miss and collision events, protects drivers and reduce associated costs. Internal policies must be developed and actively implemented that focus on engaging drivers in proactively supporting and advocating safety in the workplace. The success of safety initiatives is directly related to the level of ownership of safety management tasks by employees in safety critical positions.
Telematics systems (various)	(Horrey *et al.*, 2012)	Literature review	N/A	Review of on-board safety monitoring systems that provide feedback	Leading indicators (e.g. speed, aggressive acceleration/deceleration).	Collisions (or costs related to collisions) Trigger events believed to be	The delivery and type of feedback influences the effectiveness of the technology. Recommendations are

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
				(immediately or at a later stage).		related to safety and productivity Derived measures of risk.	based on broader insights from studies of electronic performance monitoring.
Telematics system (without camera)	(RoSPA, 2014)		57 cars and vans driven by workers aged 17 – 21 years.	Telematics device measured takes a snapshot of the individual's driving every second, and scores aggression, smoothness, anticipation and consistency. Scores are mapped onto the road network and light/weather conditions. Drivers can access their data on a web portal.	Pace: appropriate speed for the conditions Smoothness: braking and acceleration Calmness: accel. and cruising speeds –opp. of aggressive driving Anticipation: braking patterns.	Scores improved for 13 out of 17 drivers who always drove the one vehicle.	Regular reminders to review feedback in the online portal were seen as important.
Telematics system (with camera)	(Bell *et al.*, 2017)	3-group, 4–period cross-over design for each company. Two intervention groups, and a control group.	315 vehicles in total from two companies. 163 from an oil and gas company (from 13 sites across the US). 152 refrigerator trucks from a truck transportation	IVMS unit - device to provide Instant Driver Feedback (IDF) with a series of lights that indicated a risky driving event and provide supervisor with in-vehicle data for individual coaching. In-vehicle video recorded as well.	~60 individual risky driving behaviours (leading indicators) such as driving un-belted, smoking, hand-held device use while driving, unsafe stopping, and speeding.	Risky driving behaviours declined significantly more during coaching plus instant feedback (with lights) in comparison to the lights-only feedback (OR_{adj} = 0.61, 95% CI 0.43–0.86) and the control group (OR_{adj} = 0.52 95% CI 0.33–0.82). Lights-only feedback was not	There was a reduction in risky driving behaviours in all groups. However, significant reduction was seen when both IDF feedback and coaching were provided. Highlights the need for on-the-job feedback, reinforcement of new training, and knowledge of consequences for non-conformance as critical factors

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
			company (across 7 sites in the US).	All drivers were exposed to group-based feedback. A trend chart of safety incidents at their site was displayed weekly on their local noticeboards.		found to be significantly different than the control group's decline from baseline (ORadj = 0.86 95% CI 0.51–1.43).	in the jump from knowledge to behaviour change.
Telematics system (no camera)	(Sullman, 2017)	Randomised Control Trial	46 drivers completed. Randomly selected from a fleet of approx. 1500 (Russian pharmaceutical company)	Recorded whenever the driver performed a risky behaviour (see next column) *Group 1*: In-vehicle alerts and weekly feedback *Group 2:* Weekly feedback only *Group 3:* Control group.	Harsh braking and acceleration; Harsh left and right turns; Speeding 1-20km above the speed limit) and 21km+ above the speed limit); Seatbelt use.	Alerts per 100 km for the first 7 indicators reduced from 21.14 to 10.66 in Group 1 (p <.001); 22.16 to 15.34 in Group 2 (p <.001); and 23.60 to 21.22 in Group 3 (n.s.) Percentage of time that a seatbelt was used increased from 90.36% to 96.69% for Group 1 ($p < .001$) and from 76.87% to 85.71% ($p < .001$) for Group 2. Whereas, seatbelt use decreased from 83.15% to 79.92% in Group 3 ($p < .05$).	The feedback comprised a weekly email report designed by a psychologist with messaging following best-practice behavioural science principles. In-vehicle feedback combined with weekly feedback led to greater reductions in risky behaviours than weekly feedback alone (although the statistical significance of the difference was not tested). The author states this is consistent with the principle that feedback is most effective when delivered close in time to the target behaviour.

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
Telematics system (no cameras)	(Krum *et al.*, 2019)	Case-crossover	Same 20 truck drivers as in the blind spot object warning trial, 11 months in the field.	Non-video based OBMS. Drivers would get an audible verbal alert directing them to address an issue (e.g. "check your speed"). The system allowed a short grace period to correct the issue before recording a violation.	Seatbelt usage, aggressive driving, and speed over the speed limit.	Speeding violations per 1000 miles reduced by 37% in the first two weeks, but began to rebound after week 8. Seatbelt violations reduced by 56% in the first two weeks and remained around the new lower rate for the duration. No significant change in mean rate of driver-at-fault SCEs (excluding curb strikes) but the rate did decrease for 2/3 of drivers	No comment made about any specific features of the technology. There were complaints about the low speed at which seatbelt violations were recorded, and this affected the acceptability of the technology. The lack of ability for the technology to distinguish light and heavy vehicle speed limits on split speed limit highways was also a concern for managers.
Mobile phone blocking	(Ponte *et al.*, 2016)	Pre-post survey	104 drivers (97 males, 7 females, age range 25-66, mean=48.9, SD=9.1) of corporate fleet vehicles from a power company fleet.	Two phone blocking technologies: (A) software installed on the phone and (B) software in addition to an external Bluetooth device paired with the phone.	Could be used to monitor leading indicators, but more effective to just prevent the use of the phone.	Participants say they rarely or never used their phone to make a work call increased from 76% to 88% (Technology A) and 53% to 89% (Technology B).	Despite low reliability of the devices causing frustration, participants were still supportive of the technology. The author hypothesised that this was due to an existing positive safety culture (i.e. participants were biased in favour of the technology). There

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
							was no noticeable difference in preference between the two technologies.
Intelligent Speed Assistance							
Intelligent Speed Assistance	(Doecke, Anderson, Woolley & Truong, 2011)	Modelling of crash impacts.	N/A –modelling of impacts of ISA on crash data from six Australian states.	Advisory ISA (four different brands).	Predicted impacts of ISA on casualty crashes in Government fleets.	20% reduction in casualty crashes. BCRs ranging from less than one up to 4.7 (depending on upfront and ongoing costs).	No real consideration of the differentiating features of the technology except from a cost perspective (devices with greater ongoing costs had lower BCRs).
Intelligent Speed Assistance	(Fitzharris *et al.*, 2011)	Pre-Post	7 experienced truck drivers filled out questionnaire; 6 fitted devices.	Advisory ISA that measured speed and direction of travel, plus two drivers received fuel efficiency training.	Mean and 85th percentile speed. Speeding violations.	21% reduction in the odds of travelling over the posted speed limit.	The reduction in speeding was due to 25% reduction in the odds of speeding in the 80 km/h (50 mph) and higher speed zones. The fuel efficiency training was only undertaken by two drivers and findings were mixed.
Intelligent Speed Assistance	(Ryan, 2019)	Literature review	N/A	Advisory ISA Intervening/ Supporting ISA Mandatory ISA.	Impacts of ISA on fatal and serious injuries (SI) – includes studies in fleet vehicles (predicted, not actual measurements).	<u>Advisory</u> Fatalities: 4-24% SI: 0-18% <u>Supporting</u> Fatalities: 3-32% SI: 1-25% <u>Mandatory:</u> Fatal: 8-59%	ISA devices that intervene to prevent speeding (as opposed to simply warning the driver) were associated with greater reductions in speeding and predicted crashes.

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
						SI: 0-48%	
Speed monitor	(Newnam *et al.*, 2014)	Case-crossover.	16 drivers (9 males, 7 females) who worked for a religious charity and drive for work; average age 45 years.	On-board diagnostic tool (OBDII) to monitor drivers' speeding combined with a behaviour modification intervention involving feedback and goal setting.	Speeding	Reductions in the number of speeding violations per kilometre for 75% of participants. Reduction in the average rate of violations per km reduced from .031 per km to .027 per km.	The behavioural intervention was associated with increased effectiveness of the OBDI, but the effects diminished over time.
Drowsiness Recognition							
Fatigue monitoring system	(Fitzharris *et al.*, 2017)	Case-crossover.	Driver monitoring system (DMS) rolled out progressively between 2011 and 2015. There were 16 vehicles at baseline, 142 in the 1st stage of the intervention and 324 in the 2nd stage. Commercial vehicles in a short-, medium- and long-haul freight transport company in Australia.	DMS that incorporated a driver-facing camera that classified fatigue events 3 phases - *Baseline*: (no alarms or feedback); *IM-1:* (alarms only); *IM-2:* (IM-1 condition alarms plus employer feedback).	Fatigue events (classified as fatigue mitigation, drowsiness, or microsleeps) measured from a range of measurements (including eyelid opening, eyelid shape, the pupil, and head pose).	Fatigue events reduced by 66% with provision of in-cab warnings, and by 95% when real-time direct feedback from company management was provided in addition to in-cab warnings ($p<0.01$). With feedback, fatigue events were shorter in duration and occurred later in the trip, and fewer drivers had more than one verified fatigue event per trip.	This study provides strong evidence for the value of immediate automated fatigue warnings and additional significant benefit of real-time direct manager feedback.

Technology	Study	Study design	Participants	Intervention type	Leading indicators	Outcome measures	Impact of specific features of the technology
Crash Warning Systems							
Crash warning systems	(Krum *et al.*, 2019)	Case-crossover	20 truck drivers, 722,639 miles of on-road data, with 2 months baseline and 4 months with the device activated.	Blind spot object detection and warning system that alerts drivers when an object is in their blind spot using amber LEDs mounted on both wing mirrors.	Merger and side swipe safety critical events (SCEs) per 10,000 miles.	Rate of merger and side swipe SCEs reduced from .64 to .34 per 10^3 miles (not significant, p=.08).	Very simple technology. No specific comments on any aspect of it making it more effective. However, drivers did comment on the inaccuracy affecting their confidence in the device. (The device accurately detected real objects >90% of the time; 5% of detections were false positives).
Forward Collision Avoidance Technology (FCAT)	(Small *et al.*, 2014)	Modelling of crash impacts	104 crashes that had occurred within 100km of Adelaide were selected to represent crash configurations likely to be affected by FCAT systems.	FCAT systems sense other road users or objects in front of the vehicle and actively intervene to prevent a crash from occurring.	Crash types considered were rear-end, pedestrian, head-on, intersection and a proportion of hit-fixed-object crashes.	Predicted up to 40% of fatal crashes and 50% of injury crashes might be prevented with a comprehensive and effective FCAT system.	No comment on features or fleet characteristics. Likely to be more effective in urban and peri-urban settings.

4.2 Factors influencing effectiveness

This section considers factors that may influence the effectiveness of safety monitoring technologies. This section considers the influences of interrelating elements of the organisational context, feedback methods, and the characteristics of the fleet, drivers and driving context. Finally, there is a note on the effects of reliability.

4.2.1 Organisational factors

Several of the studies reviewed acknowledged that the organisational context potentially influenced the technology's effectiveness. Specifically, they noted possible effects of leadership and management style, safety culture and company policies that outlined desirable driving behaviours and prohibitions. For example, Bell *et al.* (2017) commented on the potential impact of existing company policies on driving unbelted or while using a mobile device (in a US state where neither is illegal). Hickman and Hanowski (2011) commented on the potential influence of the safety culture being different at each of the companies in their study (and this could even vary between sites within a company).

Horrey *et al.* (2012) proposed a conceptual framework to explain how feedback from telematics-based safety monitoring systems might interact with a driver's characteristics and their organisational context to influence driver behaviour. This framework is depicted in Horrey et al.'s chart, reproduced in Figure 3 below. Note that this framework has not been validated, but it is grounded in well-established behavioural science and work-performance principles and offers a potential mechanism for the role of organisational factors and feedback that could be further tested.

Horrey et al.'s framework has Michon's model of the driving task at its base Michon (1985). The model comprises three levels of control:

- ***Strategic***: cognitive activities including trip and route planning (occurring over minutes to hours)
- ***Tactical***: manoeuvres in response to dynamic traffic conditions (occurring over seconds to minutes)
- ***Operational***: ongoing physical adjustments and reactions that support vehicle control (occurring over microseconds to seconds)

Horrey et al.'s framework acknowledges that the driving environment (e.g. road characteristics, weather and traffic conditions) influences driving behaviours at each of these levels of control. For example, weather conditions (e.g. strong winds) might influence a driver to choose to take a route that avoids motorways and bridges (strategic) and adjust their speed to allow for unexpected events (tactical), but buffeting from the wind and fatigue from dealing with these weather conditions may make it difficult for the driver to maintain a steady speed (operational).

The driver's characteristics (age and experience, skills, personality etc.) also influence their driving behaviours. In the above scenario, this might result in a driver who is over-confident in choosing to drive on exposed high-speed roads (strategic) at a speed that does not allow any room for error (tactical), and potentially losing control of the steering in a wind gust (operational).

Driving for work adds a layer of organisational influence, potentially resulting in different driving behaviours when driving for work versus driving on personal time. The driver's behaviours may be moderated by their conscious or unconscious beliefs about the outcomes they may experience if they are observed driving unsafely, or if they are in an incident that is deemed to be their fault. Outcomes could be objective (e.g. losing a job or money) or subjective (e.g. losing the respect of their manager and peers).

These beliefs may be influenced by feedback, either directly from the system or through explicit and implicit messages perpetuated by the workplace about the relative importance of safety. Explicit and implicit messages may be consistent or may conflict. An example of conflicting messages would be providing drivers with a driver handbook that says they must drive within the speed limit and observe driving hours restrictions, but then giving drivers jobs that require them to meet challenging deadlines or drive for longer than is possible within those parameters.

This framework is a useful first step in moving towards understanding the mechanisms of effect of vehicle technology-based safety monitoring systems. It does not provide an evidence-base, but it provides structured theory-based hypotheses for how these systems might work, and what needs to be tested to establish an evidence base.

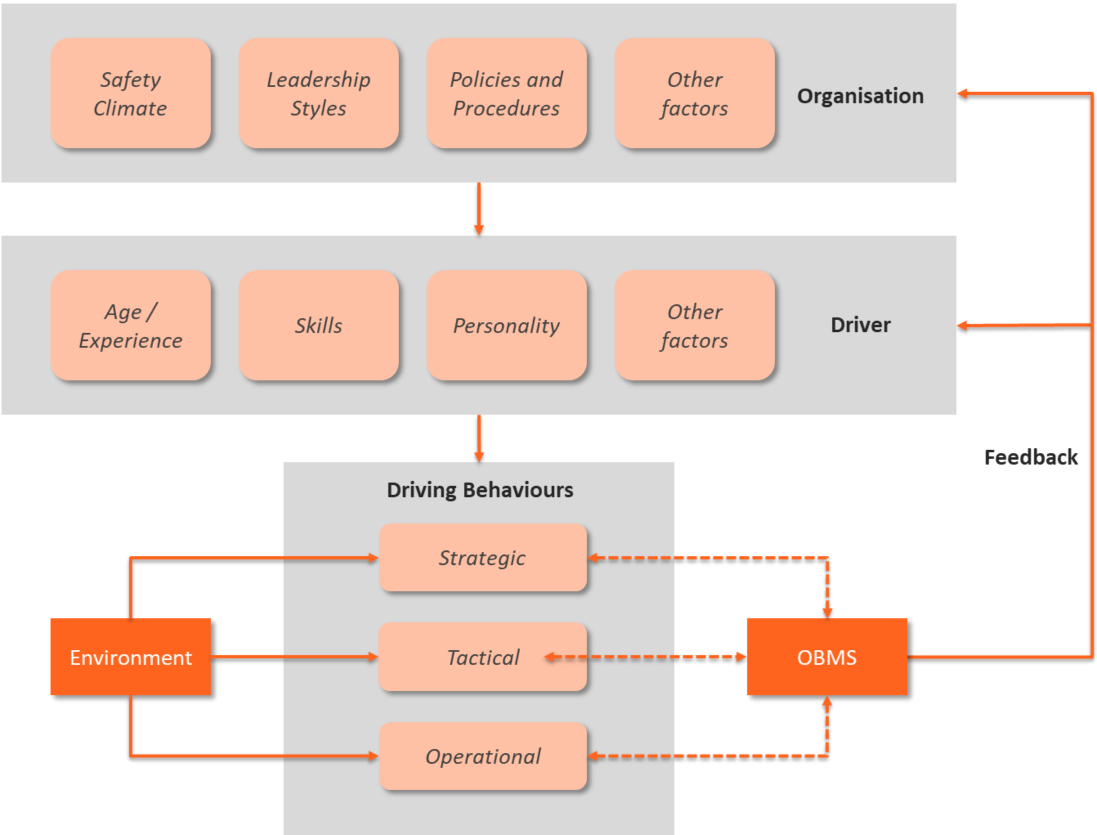

Figure 3: Conceptual framework of the role of feedback from telematics systems in moderating driver behaviour in the organisational context reproduced from (Horrey *et al.*, 2012)

4.2.2 Types of feedback and effectiveness

All the safety technologies reviewed in Table 1 included some mechanism for providing feedback for drivers. Feedback type and delivery mechanisms varied and included:

- Automatic immediate in-vehicle alerts in response to pre-set triggers, ranging from simple lights on a dashboard, audio alerts or haptic warnings, to recorded verbal warnings or instructions
- One-way provision of feedback ranging from availability of dashboard information to personalised emails about driving performance
- Interactive feedback and coaching that occurs after the event, when the driver is not driving, and makes use of data captured by the system (including video if this is available)
- Real-time interaction and intervention (e.g. a supervisor calling to check driver welfare and implement safety measures when drowsiness events are captured).

The list above is ordered by what appeared to be the most to least common forms of feedback appearing in studies of the effectiveness of safety monitoring technologies. Probably not by coincidence, it is also ordered from least to most interactive and least to most resource intensive.

4.2.2.1 Previous literature review on feedback and telematics systems

Horrey *et al.* (2012) reviewed the literature on telematics-based safety monitoring systems that included a mechanism for providing feedback for drivers. At the time, they found that the role of feedback had been insufficiently considered in studies of the effectiveness of telematics. They supplemented their review with information from a neighbouring domain: the electronic monitoring of workers in mostly computer-based workplace settings.

They found that a sense of interpersonal and procedural fairness was critical to employee responses to feedback (p.54). The degree of perceived fairness was influenced by:

- source of feedback (face to face, via supervisor, or through a computer)
- constructiveness of feedback (better if it was specific, considerate in tone, devoid of threats and did not attribute poor performance to an inherent personal characteristic)
- control over feedback, including the timing and frequency of feedback
- the amount of input that employees had over the design and implementation of the system
- the extent to which electronic performance monitoring results can be challenged.

Horrey *et al.* (2012) highlight that for truck drivers, there is a potential conflict between the goals of telematics systems and other management pressures to decrease delivery times. This is important, because it directly affects perceptions of fairness (and actual fairness), and is an issue that organisations need to attend to when planning to integrate vehicle safety monitoring systems into their business. This issue is relevant to any organisation that explicitly or implicitly puts pressure on drivers to push safety limits. For example, by scheduling more work than can be delivered if the driver takes all their breaks, keeps to the speed limit, stays within working hours, follows safe work procedures etc.

Drawing on organisational management literature as a potential source of guidance on feedback, they summarised their findings with the advice in Figure 4.

- "Provide immediate feedback when the unsafe behaviour is persistent and correctable (e.g., seatbelt usage, following distance).
- The intrusiveness of feedback should be commensurate with the urgency of the information to be conveyed.
- Feedback should be positive (if possible) and constructive.
- Training and development should be emphasized over punishment.
- Drivers should experience their errors and not just be told about possible errors and their solutions.
- Drivers should have a role in the feedback – in the control over the timing and frequency or in providing input into the design or implementation."

Figure 4: Advice on feedback from (Horrey *et al.*, 2012, p.54)

Hickman and Hanowski (2011) also provide some considered thoughts on the issue of feedback based on organisational psychology. Specifically, they note that pairing goals with feedback is likely to increase the effectiveness of feedback. They did not try to compare types of feedback in their study, but they did note that there were differences in adherence to feedback protocols, and that this was likely to explain part of the difference in results between the two carriers in their study.

Some of the more recent studies (e.g. Bell *et al.*, 2017; Fitzharris *et al.*, 2017; Sullman, 2017) have attempted to disentangle the effects of immediate in-vehicle feedback with later coaching or offline feedback via email. In line with Horrey *et al.*'s findings, they have generally found that coaching appears to have a greater impact on safety indicators than immediate automated feedback, and that a combination of immediate feedback and coaching may be more effective than either alone. These studies are examined in more detail below.

4.2.2.2 Tailored email feedback versus in-vehicle alerts

(Sullman, 2017) compared the relative effect of offline feedback from a telematics system combined with immediate in-vehicle feedback (Group 1) with offline feedback alone (Group 2) in a randomised control trial. He used a sample of 50 drivers split into the two treatment groups (Group 1 and 2) and a control group (Group 3) and compared drivers for a 17-week baseline and 17-week intervention period.

The instant feedback was in-vehicle alerts and the offline feedback was individual weekly emails summarising the driver's performance compared with the rest of their organisation. The offline feedback was designed "using insights drawn from behavioural science" (although no further detail is given on what this entailed). Seatbelt use increased significantly, and risky driving behaviours decreased significantly in both intervention groups. The improvements appeared to be greater for immediate and offline feedback combined compared with offline feedback alone. However, there was no statistical comparison of the change in Group 1 with the change in Group 2 or the control group. The sample for this study was quite different to most of the other studies, being relatively young and predominantly female.

4.2.2.3 Goal setting and written feedback reports

Newnam *et al.* (2014) examined the effects of goal setting and feedback. For three weeks, drivers were given a written report on:

- percentage of time they spent within the speed limit and exceeding the speed limit
- percentage of time exceeding the speed limit compared with other drivers participating in the intervention
- their 'safety' rank compared to other drivers in the intervention.

The aim was to challenge drivers' key salient beliefs regarding their speeding behaviour in the work vehicle. The driver report was delivered in a booklet inscribed with the slogan: "Caring for others extends to when you are behind the wheel too. So, when driving BE the example that others should follow. Keep watch on your speed and always stick to the limit".

This slogan was intended to tap into motivations inherent to the drivers' roles (a 'caring profession'), encourage them to compare themselves with others and show leadership (which tied into the ranking in the report). The final sentence provided a tangible strategy to reduce speeding.

Researchers held weekly discussions with drivers to plan how they could reduce their over-speed violations for the next week. Drivers discussed when and why they violated the speed limits with the researchers. The researchers suggested strategies e.g. "ring ahead if you are going to be late" and "use cruise control to ensure you keep within the speed limits".

There were small but significant reductions in speeding events, but effects diminished after the feedback sessions stopped.

4.2.2.4 Supervisory coaching versus in-vehicle alerts

Bell *et al.* (2017) also compared the effects of two types of feedback: immediate in-vehicle alerts and supervisory coaching.

A telematics system was installed in a sample of 315 trucks in two companies: one from the oil and gas industry and the other general freight trucking. Safety events triggered camera recordings as described previously.

There were 60 behaviours measured, covering a wide range of domains: driving errors, failures in vehicle control, poor stopping, speeding, poor situational awareness, distraction, fatigue events etc. Supervisors had access to a portal where they could review videos of their drivers' risky driving behaviours that exceeded a certain threshold of severity. Supervisors were instructed to aim to coach drivers within a week of any such incidents. They were given training in coaching. The coaching was described thus:

> 'Goals of the sessions included clearly defining the high risk behaviours observed, reinforcing company policies and safe driving habits, rewarding safe driving behaviours, and the suggestion to present the information in a positive manner, akin to a coach "going over game films to improve performance" with an athlete' (p.127).

The trial had a control group, but it is important to note that all drivers (including controls) were exposed to a form of feedback through the display of a trend chart summarising their depot's performance through the metric of miles driven per week without a severe incident.

Bell et al. found that immediate in-vehicle feedback alone was not associated with a significant effect on risky driving behaviours compared with a control group. However, noting that all drivers were exposed to feedback on their site's safety performance, it is probably fairer to say that the in-vehicle feedback was no more effective than in-group feedback.

Coaching combined with immediate in-vehicle feedback was associated with a significant reduction in risky driving behaviours compared with a control group.

4.2.2.5 Direct manager intervention versus in-vehicle alerts (haptic and auditory)

As described in section 4.1.3, Fitzharris *et al.* (2017) compared the effects of an in-vehicle coaching intervention with in-vehicle alerts in a freight company.

At baseline, there were no alarms or feedback. The first stage of the intervention (IM-1) involved alarms only: an auditory warning ("fatigue detected") or an auditory tone (depending on vehicle), as well as a haptic warning consisting of vibration pulses through the base of the driver's seat. In the second stage (IM-2) there were alarms plus employer feedback. In IM-2, feedback was provided to the driver and to the company directly. When an event was detected, the transport company's fatigue management plan (FMP) was initiated: the company's central dispatch centre was notified of the fatigue event(s). The supervisor talked to the driver directly about whether to take mitigation actions such as taking a break or "swapping out" with another a driver.

Fatigue events reduced by 66% with provision of in-cab warnings, and by 95% when real-time direct feedback from company management was provided in addition to in-cab warnings ($p<0.01$). With feedback, fatigue events were shorter in duration and occurred later in the trip, and fewer drivers had more than one verified fatigue event per trip. The study indicated a significant effect of immediate automated fatigue warnings, and additional significant benefit of real-time direct manager feedback.

4.2.3 Role of driver characteristics, fleet type and driving context

The potential role of the driver, fleet type and driving environment have been touched on in Section 4.2.1.

The most commonly featured drivers and driving environments in the studies that were identified for this review were truck drivers, especially long-haul drivers. These drivers were, on average, more likely to:

- be male and older than the general driving population
- drive vehicles that were directly owned or leased by the organisation they drove for
- be employed, with driving as their primary job function.

The only study that attempted to systematically compare effectiveness by fleet type was a study identified in the (Grayson & Helman, 2011) review. (Wouters & Bos, 2000) found significant variation in effectiveness of an early type of IVDR across fleet types. They observed 270 vehicles with IVDRs installed and 570 control vehicles across seven fleets. Vehicle types included company cars, taxis, vans, coaches and trucks. Over 3,100 vehicle years, there were 1,836 crashes recorded (severity level not specified). There was a 20% average reduction in crashes after adjusting for changes in the control group. This effect varied between a (not statistically significant) 13% increase in crashes among heavy trucks to a statistically significant 72% reduction among coaches. However, the study was unable to account for variations in organisational approaches, including the ways that feedback was applied.

Some of the other studies identified in this review included more than one type of vehicle or more than one type of driving context. For example, one study included long-haul freight drivers and oil and gas maintenance drivers, and found some differences in effect between the fleets (Bell *et al.*, 2017); another study featured drivers in sales roles who were predominantly young and female (Sullman, 2017); and one study of community support drivers with approximately even numbers of male and female participants (Newnam *et al.*, 2014). However, this is far from a systematic comparison of the effectiveness of the technology in different fleets or different organisational contexts.

Other fleet characteristics and driving contexts that require more attention in studies of the effectiveness of vehicle safety technologies are considered below. These groups have been chosen for special attention because they are increasing in prevalence, are a known higher risk group of drivers, or both.

4.2.3.1 Drivers in the gig economy

The term ‘gig economy’ is being used here to describe systems of work where people get paid per task (or ‘gig’) and in which service providers are linked to service users via an app or other digital platform. On-demand passenger services and food delivery are well-known examples of transport-related services that operate in the gig economy. However, there are many lesser known organisations distributing transport tasks through digital platforms, for example parcel delivery dispatch companies.

The Health and Safety Executive recently reviewed the health and safety implications of the gig economy (HSE, 2019). They found that approximately 2.8 million people in the UK participate in the gig economy. Most of the types of work performed by workers in the gig economy involve at least some driving between locations (e.g. cleaner) and some involve predominantly driving (e.g. food and parcel delivery, taxi driving). They found that:

- People in the age range 18 to 34 are substantially over-represented (56% of gig economy workers are aged 18 to 34 whereas they constitute only 27% of the general population).
- As drivers, gig economy workers are likely to be at increased risk of fatigued driving due to excessive hours of work.
- Drivers may also be at increased risk of distracted driving from the apps through which their work is dispatched and managed.

Christie & Ward (2018) conducted in-depth interviews with 48 drivers and riders (including self-employed taxi drivers and courier drivers) as well as an online survey with 231 respondents. They explored the drivers' experience of risk and its management amongst drivers and their managers engaged in the gig economy. They found that this model of work can lead to drivers and riders feeling under significant pressure to engage in unsafe driving behaviours including:

- exceeding speed limits to try to meet deadlines
- interacting with their mobile phone while driving (for example, to accept and reject jobs)
- driving while fatigued from excessive hours of work and/or mental overload (Christie & Ward, 2018; Christie & Ward, 2019).

Christie and Ward (2019) provided a model of the themes arising from their qualitative research with drivers and riders that illustrates how driving and riding performance may be affected by the way that the gig economy operates Figure 5). The model is conceptual only (as it has not been tested and validated), but it is a useful starting place for considering the interactions between the business model and driver/rider performance, as well as opportunities for intervention. It also has some synergies with Horrey *et al.*'s model discussed in 4.2.1.

The authors acknowledge that their sampling method (a self-selecting sample) means that the results of the survey may be biased. For example, towards drivers who have grievances that they want addressed. However, in the absence of further research, their results highlight potential risks that organisations contracting self-employed drivers and riders should consider in their risk assessments.

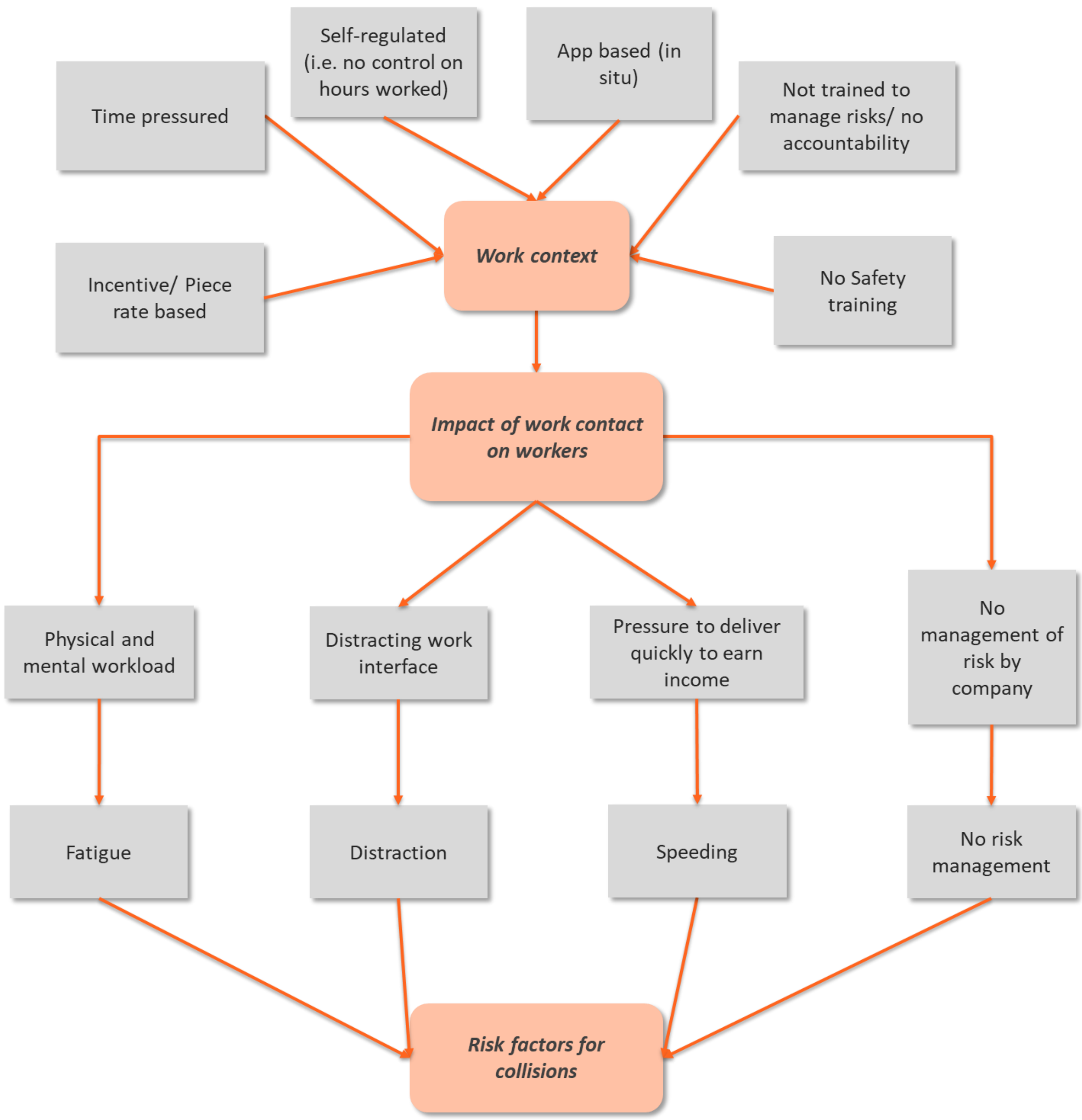

Figure 5: Factors potentially linked to increased risk of crashes among drivers and riders in the gig economy reproduced from (Christie & Ward, 2019)

There is some disagreement over whether gig-economy workers in the UK should be considered self-employed. Regardless, it is clear from the health and safety legislation that contracting organisations are not devoid of responsibility for managing the risks associated with the work that they control. From an occupational risk perspective, enforcement agencies and courts can look beyond the 'self-employment' label to consider the way the employment relationship operates, including the level of control a worker has over the way they work.

The apps used to distribute tasks to workers in the gig economy are integral to the system of work. The design of these apps could exacerbate the safety issues noted above (stress, distraction and fatigue). For example, the apps for self-employed taxi drivers operate by notifying drivers of trip requests through auditory and visual alerts (like beeping and flashing) until the driver responds to the request by tapping on the screen. The alerts can be quite intrusive (e.g. "the app used to allow me to mute the sound it makes when a delivery request comes in, but now this option has been removed" – reviewer on Google Play "Greg", 5 May 2020) and some apps send drivers new trip requests as they approach the destination of the current job. This could lead to the driver attending to multiple things other than the operational and tactical elements of the driving task, taking their eyes off the road and traffic for multiple seconds. This system exacerbates the motivation inherent in the work model to get to the next job as quickly as possible without a break.

4.2.3.2 Younger drivers

Young, novice drivers are known to have a higher road risk than older, more experienced drivers (Simons-Morton, 2019). In this review, no study was found that systematically tested the interaction between age and effectiveness of vehicle technology-based safety monitoring systems in the work context. However, naturalistic driving studies using telematics have been reported for studies of young-novice driver risk. These have identified that young-novice drivers have a significantly greater rate of abrupt manoeuvres than in older adult drivers (Simons-Morton, 2019). It is therefore possible that the use of telematics in a fleet setting could identify at-risk young drivers, and with appropriate management, feedback and coaching reduce their crash risk.

The RoSPA (2014) study described in section 4.1 examined outcomes for drivers aged 17 to 21 who had a black box in their work vehicle linked to a web portal where they could review their driving performance. Overall, for the group that always drove the same vehicle (17 in total), 13 showed improvements in driving performance as measured by a composite score based on appropriateness of speed, smoothness and calmness of driving, and anticipation. However, the study was not intended to be a quantitative evaluation and no firm conclusion can be drawn on effectiveness for the younger driver group. This is especially true because one would expect a novice driver's skill at driving to improve over a nine month period.

However, as noted above, younger drivers are over-represented in gig economy jobs that involve a lot of driving. For example, fast food and parcel delivery and sales. Addressing safety issues for gig economy drivers therefore has potential to significantly improve the safety of young people driving for work.

4.2.3.3 Older drivers

Commercial driving is associated with an ageing workforce and associated health impacts that have ramifications for road safety (HSE, 2017).

Taxi and private hire vehicle (PVH) driving has also traditionally been the domain of older males, and despite younger people being over-represented in the gig economy, there is no evidence that this is reducing the age profile of taxi and PVH drivers. In 2018/19, the average age of 'taxi and cab drivers and chauffeurs' was 47, with only 29% of drivers being aged under 40. Overall there has been a slight upward shift in the age profile of these drivers in the last 10 years (DfT, 2019).

There has been research that has found lower levels of acceptance, adaptation and adoption of new technology in older drivers. However, in this review, no study was found that systematically examined the interaction between age and effectiveness of vehicle technology-based safety monitoring systems in a work-related driving context.

4.2.3.4 *Cyclists and motorcyclists*

Bicycles (including electric bicycles), scooters and small motorcycles are increasingly being used for food delivery. However, there was no research found in this review that specifically considered the effectiveness of vehicle technologies in providing employers with vehicle technology-based safety monitoring systems (even when applying this term in its broadest sense to include GPS trackers and mobile phone applications).

4.2.4 Reliability of technology

Some studies reported dampening effects when technology was unreliable or thresholds for triggering warnings were perceived as 'too sensitive'. For example, participants in the Krum *et al.* (2019) study were less trusting of lane change warnings due to some unreliability in detecting objects that were present, and mistakenly triggering when there was no relevant object present. They were also less accepting of technology that triggered seatbelt warnings in low-speed manoeuvring scenarios. However, there has been little systematic public examination of the effects of trigger thresholds on safety outcomes.

5 Consultation

The aim of the stakeholder consultation was to gather examples of successful and unsuccessful implementation of technology in fleets and consider opinion from relevant stakeholders and experts. The topic guides for the interviews were designed to gather intelligence on how telematics-based safety monitoring systems are being integrated into fleet settings, barriers to their implementation, broad lessons learned in implementation, and how such technologies can be successfully integrated into the ‘Plan, Do, Check, Act’ approach.

There were two broad categories of interviews: interviews with people from organisations that had implemented telematics-based safety monitoring systems; and interviews with other stakeholders and experts who may have relevant insights and interests in such technology. Their responses are synthesised in this section.

As is normal in workplaces, some of the people originally involved in planning the implementation of systems had moved on since implementation. Therefore, some of the questions about planning and implementation are based on a smaller set of responses, or less detailed information from individuals who later managed the systems.

The examples from organisations that have implemented telematics systems generally reflect successful rollouts and good practice. Where challenges are mentioned, they are generally in terms of how they were overcome. Insights into less successful practices and barriers to successful rollouts were offered by stakeholders, which can be found in section 5.2.

5.1 Implementation experiences

5.1.1 Organisational context

The characteristics of the organisations included in this study are listed in Table 2. The organisations ranged in size from Small and Medium-sized Enterprises (SMEs) (150 employees) to extremely large (over 450,000 employees).

The types of organisations were varied and included parcel delivery companies, general haulage, engineering services and enterprise information management services.

The fleets also varied, including some that were predominantly trucks, others that were predominantly vans and some that were a mix of trucks, vans and cars.

Table 2: Organisation and fleet characteristics

Business type/ service	Employees	Vehicles	Driving role
Civil eng. consultation & construction	20,000	7,000 (even mix of cars, vans and trucks)	Ancillary
Information management	2,500 in the UK	220 (including: 50 trucks, >7.5 tonne; 170 large vans, 3.5 tonne)	Both
Defence services	450,000	250,000 (wide variety, including cars, tanks, buses and HGVs)	Both
Rail network manager	40,000	9,000 vehicles (including 600 large/HGVs, 6000 large vans, and 1200 cars and small vans)	Mostly ancillary
Parcel delivery and courier	150,000	49,000 vehicles (exc. trailers), inc. approx. 4,000 tractor units, 2,000 rigid trucks, 4,000 medium/ large vans, 39,000 smaller vans and 2,000 company cars.	Ancillary
Haulage	500	400 trucks	Primary
Paper logistics	150	100 trucks	Primary
Parcel delivery and courier	1000*	370 tractor units, 550 large vans (3.5 tonne), 17 Lutons, 30 rigid trucks (7.5 tonne) and a couple of 18 tonne trucks. Self-employed drivers provide own vans.	Primary

* plus a seasonally variable self-employed workforce

5.1.1.1 *Purpose and benefits of technology*

All interviewees mentioned improving ‘safety’ as a purpose of the systems they had implemented. Some mentioned related purposes such as reducing insurance premiums (which could be in the millions for a business that has many vehicles) or repair costs. Others mentioned needing to be able to monitor locations of lone workers in remote locations to ensure their safety. For some, a specific crash or cost problem had prompted the investigation into telematics systems.

“In the ten years to 2008, [the company], had rolled over 34 fleet vehicles. So about three a year were rolling over; cost the business somewhere in the region of a hundred thousand pounds a go. But the real risk was to multiple lives…”

For others, there was a clear focus on addressing risky driving behaviours:

“We can see our drivers that are at risk… we can see drivers that are traveling too close to the vehicle in front. We can see drivers that are swerving at the last minute. You know, we can see drivers slamming on their brakes really hard, and it allows us to get in front of the next accident. It allows us to talk to that driver, coach him, show him on the video evidence where he's going wrong.”

In addition to safety purposes, most mentioned other purposes and benefits related to costs and efficiency such as reducing their fuel bill, optimising route planning and vehicle utilisation.

5.1.1.2 Driving and employment context

In three of the organisations, driving was ancillary to the primary role of their employees who drove regularly and had telematics-based safety monitoring systems installed in their vehicles. For example, engineers who drive to and around sites, and service or salespeople who drive from customer to customer. These drivers may still be driving for multiple hours per day in a work vehicle.

For other drivers (e.g. delivery drivers and haulage drivers), driving was considered their primary role. This group includes commercial drivers who were required to undergo periodic training to maintain their Certificate of Professional Competence (CPC). These drivers and the organisations that manage them are subject to more regulatory requirements and greater scrutiny than others. The organisations that employ them need well organised systems to manage and monitor their compliance, and this was reflected in the comprehensiveness of the systems in place. This is discussed more under fleet characteristics in section 5.1.1.3.

For those organisations that employed ‘professional drivers’, there seemed to be a slight tendency to have more of a focus on coaching for driving performance as opposed to just monitoring for problems.

There were also differences in employment conditions. One interviewee had experience implementing a system in an organisation in which truck drivers were salaried, and another in which they were paid by the load. They mentioned that it was “more difficult” to develop a safety culture with drivers in the latter circumstances because these drivers spent more time away from base and had less contact with supervisors.

5.1.1.3 Fleet characteristics

As noted, the fleets were varied, including some that were predominantly trucks, others that were predominantly vans and some that were a mix of trucks, vans and cars. This had implications for the types of safety monitoring systems installed and how comprehensive they were.

More than one of the interviewees said they had more comprehensive systems in their trucks than in their lighter vehicles, or that they had systems in their trucks but were only starting to look at expanding them to their lighter vehicles. The reasons included the relative value of the vehicle and risk per vehicle, and that consequences for drivers and operators of large vehicles involved in crashes are more severe. One interviewee, who had a particularly comprehensive suite of monitoring technologies, talked about the seriousness of the legal and financial risks that they were aiming to manage:

> *“… these drivers sometimes risk jail… and so do our operating license holders... Because had that driver been found at fault, had the vehicle being found at fault, had his training records not been up to date, you know, it would be more than just the driver standing in court… It’s people's livelihood. It's my livelihood. It's my transport operator licence holder’s livelihood. … It's the driver’s livelihood… it is so serious out there on the road.”*

At the other end of the scale, it was noted that it may not be possible to install systems in vehicles that were not owned or directly leased by the organisation, but which were frequently driven for business purposes. For example, drivers in the gig economy and grey fleet drivers. One company mentioned they were considering trialling a potential ‘plug-in’ device for company cars that would enable some monitoring to occur.

5.1.2 Implementation

5.1.2.1 Policies and related documentation

Most organisations said they had a standalone work-related road safety policy (for example, a fleet safety policy, a safe driving policy). For most, the telematics-based safety monitoring system was mentioned in these policies, which set out how the system could be used to monitor vehicle use and reduce road risk in the workplace.

5.1.2.2 Procurement processes

Not all interviewees were involved in the procurement of the safety monitoring system deployed in their fleet. Of those that were:

- One noted that they had the opportunity to pilot a system and observe the effects before committing to a full implementation.
- Some organisations mentioned putting together a business case for introducing the system.
- Larger organisations noted that they had gone through a formal tender process to select a supplier.

5.1.2.3 Consultation and communication

Those involved in initial implementation of systems tended to mention extensive communication with staff about the purpose and functionality of the systems.

> *“So we've got screens in the transport offices. We did a video package for it. We do driver one-to-ones and while we were talking to the drivers we also [told drivers about the introduction of the new system] there. Notice board information, even showed some of the videos that we've seen on it to help show drivers… this is good and … working with the unions as well, so the unions talk with the drivers”*

Some mentioned the challenge of consulting and communicating across large networks of staff that spent significant amounts of time alone on the road. They used a variety of internal communications channels to ensure that they reached staff (e.g. email bulletins, cascading information down through levels of management to brief staff in meetings, information posted on noticeboards or television screens in depots, briefings to staff associations and unions). The extent of absorption of this information was not well known.

Some talked about cascading information to depots and drivers through their management structures in the form of paper-based bulletins, emails and presentations. This cascading approach ensured that information was systematically distributed to all levels of the organisation, including to drivers and their line managers.

5.1.2.4 Introducing and rolling out systems

The organisations in this study were SME to very large, and most were geographically dispersed. This presents a significant challenge for implementation of systems across the organisation and makes a standardised system that can be rolled out across a large organisation very attractive.

To overcome this challenge, at least three of the interviewees mentioned trialling or piloting implementation at a single site or depot first. They used this as an opportunity to test the technology and to address issues before rolling out the program to the rest of the organisation. A couple talked about identifying a depot manager who was committed to safety and using them for the pilot rollout. They used this period to refine their procedures including driver training, education and coaching.

One interviewee talked about how he had the system installed in the senior management's vehicles so that management understood what the drivers were experiencing and to help build trust with drivers.

When introducing the systems, some organisations talked about having a moratorium on disciplinary action, where unless a driver did something illegal, they would not experience a disciplinary in the initial grace period of up to 3 months. However, instances that would have triggered disciplinary action would be highlighted during coaching so that drivers could learn what they needed to do differently.

Some of the organisations commented on the influence of unions in determining what they did or did not do with their safety monitoring systems, including:

- restrictions on 'risk profiling' drivers (i.e. the kind of scoring that enables companies to compile league tables)
- requirements that managers submit a case for accessing any individual level data
- requirements for an emphasis on coaching and supporting drivers to improve.

Those that mentioned union involvement and expressed satisfaction with negotiated outcomes, emphasised that it was important to be very clear on the safety benefits for drivers of any system features and/or monitoring capabilities. One said:

> *"…if we see drivers that… aren't quite up to par or are at risk of a serious incident then the technology is there for us to be able to help that driver because at the end of the day the driver doesn't want to have a blameworthy incident. The driver doesn't want to lose his legs in an accident, or a life in an accident. He wants to go home at the end of each shift, not hospital… You want the best for your drivers…"*

5.1.2.5 Use of cameras

Organisations used external cameras to monitor what was happening around the vehicle at the time that a safety event was triggered on the telematics system, and internal cameras to monitor what the driver was doing at the time.

One interviewee who had implemented driver facing cameras stated:

> *"I come across a lot of companies that have got incredible camera systems on their trucks, 360 degrees externally… and honestly they are only useful in terms of insurance litigation. They have no value in terms of driver training."*

Driver facing cameras allow analysis of driver behaviours that may have contributed to incidents or events being triggered. Such behaviours, which cannot be picked up from the telematics system, include things like not wearing a seatbelt, smoking, talking/texting on a phone, eating and drinking etc.

Cameras can also increase efficiency in producing evidence when a collision occurs. This accelerates the process for police investigations into serious crashes, which reduces costs to the business and stress on driver and managers.

An interviewee, who had external only cameras installed in his fleet, described a very recent situation where a driver had been involved in a motorcycle fatality. From the camera, they assessed that there was nothing the driver could have done to prevent the crash, and the telematics data showed the truck had been traveling steadily under the speed limit.

The interviewee observed that in situations where the driver is clearly not at fault, it is reassuring for them to have the footage and the telematics data to back up them up and help to resolve the situation quickly.

This was not the only incident in which the cameras had been useful. They had also backed up a driver's story of a third party driving away from an incident without stopping at the scene in the week prior to the interview.

The interviewee said they "lock away" footage of crashes that result in fatalities and serious injuries. This ensures privacy requirements are upheld and protects other staff from exposure to traumatic footage. The business offers counselling for anyone who has viewed the footage, as well as the driver involved in the crash.

The interviewee emphasised that drivers and operator licence holders can face jail if the driver was found to be doing something unsafe and/or illegal, so being able to monitor and show that you've done everything that you could reasonably be expected to do to reduce the risk is important. This includes things like having up-to-date training records for the driver and evidence that the truck is in a safe condition to drive. The interviewee felt it was invaluable to have the insights that a telematics device has to offer.

5.1.3 Monitoring and evaluation

5.1.3.1 Measuring safety: Leading and lagging indicators

Driving is one of the riskiest work tasks and accounts for a significant portion of serious workplace injuries nationally. However, unless the fleet is very large (i.e. greater than 50,000 regularly driving) or the problem is very severe, the numbers affected within an individual workforce are usually very small. This makes it difficult to observe trends and changes.

For most, the closest that they can get to a lagging indicator is 'reportable incidents' such as those in which there is a minor collision that may or may not result in a fatality, injury or vehicle damage. These were sometimes monitored using the telematics-based devices that recorded *g*-force events, but this was always backed up with a more traditional incident recording system that required additional investigation and analysis of causes. Some used insurance claims and premiums or repair bills as indicators. A few counted speeding violations.

Leading indicators measured from the devices nearly always included *g*-force measured events such as harsh acceleration, braking, swerving and cornering. Speed and exceeding the speed limit were also frequently measured. Following distance was also popular – measured using cameras or sensors. A couple of stakeholders also mentioned that they measured idling[4]. Seatbelt wearing, fatigue events and distraction events (e.g. mobile phone use) were only mentioned in fleets with driver facing cameras, which was rare. In the organisations we spoke to, these things were recorded only when the camera recording was triggered by a g-force event or a following distance event. The camera recordings were 12 seconds before and 4 seconds after an event.

Some organisations also measured 'positive' leading indicators such as amount of coaching.

5.1.3.2 Reporting and monitoring

More than a couple of interviewees talked about their efforts to get meaningful reports out of their systems. Systems can produce very large amounts of data, making it difficult for businesses to identify what is important and where they should focus their attention.

One organisation talked about having to employ data scientists to extract and analyse the data and design a digital dashboard. Their new safety dashboard has made a huge difference to the way that the organisation interacts with the system. It gives management at every level visibility of data for the business structure beneath them summarised by operations manager and delivery office. The fleet team and safety team can also see all data. Trends are monitored by vehicle and by office.

Another talked about doing the work of summarising and analysis themselves and enjoyed working with the data. However, it is not usual for a senior manager to also be a data analyst,

[4] Drivers are generally told to turn off their vehicles and not let them idle when stopped (for example, when loading or unloading). Some stakeholders observed that drivers who often broke this rule were also more likely to break other rules and be involved in incidents.

and ongoing data outputs and reporting is something that should be considered when procuring a new system.

Most organisations mentioned cascading results down through reporting lines to line managers and up to senior executives. This could be as frequently as weekly reports, but some also mentioned data dashboards that could be published on an Intranet, emailed out or displayed in depots.

These ranged in detail from graphs that summarised and compared performance at the regional, site and/or team level to league tables that gave details on individual driver performance.

Most organisations said that managers had direct access to the system to monitor driver performance, and to use in coaching. One or two said that driver performance was only accessible by drivers themselves and it was not clear to what extent performance metrics were available for monitoring and evaluation.

To maintain a focus on the safety performance, key performance indicators (KPIs) for drivers and managers often included safety benchmarks or goals. For similar motivational purposes, league tables were used in some organisations to create competition between depots, regions and/or countries. Some organisations mentioned reporting this data back to their executive leadership at various levels of detail.

5.1.3.3 Evaluating outcomes

Not all interviewees were able to say whether their system had been evaluated for impact. Some were very clear that change had occurred. The company mentioned above that had 34 rollovers in the ten years to 2008 reduced rollovers to zero from 2009 to the time of the interview (May 2020). However, this organisation also made other significant changes such as introducing stability systems that would also have contributed to this safety improvement.

Working with insurers was also mentioned as a way of monitoring impact. For example, one interviewee related his experience:

> *"…our insurer came to us and said 'what have you done? Because you've reduced collisions on the road by 70%'" [after two years of having the system installed]*

This organisation also saved a significant amount of money on premiums as a result of their safety improvements.

None had done a rigorous evaluation that related specific features of the system with behaviour change and safety outcomes, and none mentioned a thorough cost-benefit analysis.

5.1.4 Feedback and coaching

Coaching was measured by a few of the organisations, although it was not always clearly defined. One clear example of a process for coaching was offered. It can be summarised as follows:

1. *“Make sure they understand the system.*
2. *Ask them what is contributing to their scores and try to uncover if there is any problem that needs to be addressed.*
3. *Ask them to address behaviour.*
4. *Monitor to see whether there is a change.*
5. *If there is no improvement, put the driver through a driver training course (including information on how the system works).*
6. *If no improvement is observed, remove from driving. (The interviewee noted that it was very rare to get to this last step).”*

Some interviewees mentioned a ‘publicly praise, privately coach’ approach to motivating improvements in driving behaviours. In the ‘publicly praise, privately coach’ method, all drivers are scored based on the frequency and/or severity of events that they have triggered. The lowest scoring 10% of drivers (lowest risk) are praised publicly and top 10% (highest risk) are coached (proportions may vary from organisation to organisation). However, it should be noted that some concern was raised regarding telematics being used to rank and risk-profile employees.

One interviewee talked about a more elaborate approach, whereby high performing drivers received badges that they could display, and they feel proud of their achievements. They also get high street vouchers and certificates, as well as driver of the year awards.

Another interviewee who was looking to improve results from the system they had installed spoke of results from a pilot of more comprehensive feedback and coaching. They had observed significant improvements in one depot that had a serious crash problem. They noted that in other depots where they just had dashboard ‘traffic light’ feedback with no follow up from managers or trainers, drivers seem to revert to previous behaviour after a while.

Some systems come with coaching programs already defined. However, they may need to be tailored for the local need. For example, “the coaching program … is fairly well defined… [but] it’s an American system so we’ve refined it to suit ourselves”.

5.2 Expert and stakeholder insights

5.2.1 General sentiment

Nearly all interviewees expressed support for the use of telematics-based safety monitoring systems but differed to a greater or lesser extent in their views of how such systems should be implemented and what features they should include. These points of difference are discussed further in the sections below.

One transport department interviewee noted that they would value being able to refer organisations to guidance on this topic from the HSE. They already refer drivers to guidance from the Royal Society for the Prevention of Accidents (RoSPA), Driving for Better Business (DfBB) and the Scottish Occupational Road Safety Alliance (SCORSA).

While the union representative expressed in-principle support for the use of telematics-based safety monitoring systems to protect drivers' safety, they had some reservations based on observations that:

- safety was often not the primary purpose of organisation's implementing telematics-based monitoring systems
- some organisations have misused systems (e.g. used cameras for covert surveillance of employees in a work yard)
- some drivers experience increased stress from feeling like they are constantly under surveillance
- some organisations over-rely on systems that record events reactively rather than proactively mitigating fatigue through driver workload and shift planning.

In support of the first point above, another interviewee stated that the selling point was usually reduced fuel bills. The potential savings on fuel bills in a large fleet was orders of magnitude greater than safety savings from insurance and repair costs. This viewpoint is supported by a quick search of the internet for 'fleet telematics'. The sales pitches of the first few products returned by the search are firmly focused on tracking vehicles and fuel economy.

5.2.2 The role of telematics / benefits

Most stakeholders thought the primary role and benefit of telematics-based safety monitoring systems should be to help employers manage drivers to address risky driving behaviours and thereby reduce risk. As driving solo involves remote and often isolated work, being able to track drivers' locations was also seen as a safety benefit.

Some also noted that improving driver behaviour through safety monitoring systems could help reduce organisations' reputational risk from involvement in serious crashes and high-profile court cases. Some noted that proactively managing risk meant managers should be dealing with fewer incidents and have more time to focus on the rest of their job. Many also mentioned the role of telematics in defending drivers who were "doing the right thing".

Those stakeholders who had oversight of the effects of telematics-based safety monitoring systems across organisations noted that they had observed reductions in incidents. This includes an insurer who only covers organisations that use telematics. This interviewee stated that their data showed significant overall reductions in fatalities and severity levels of claims in organisations that implemented telematics systems.

One interviewee noted that telematics could be useful in helping to "nudge" drivers towards safer behaviours. In the previous section, organisations noted that its value was in providing data input to coaching, in raising awareness of safety risks across the fleet, and promoting friendly competition to improve.

Stakeholders generally agreed that telematics-based safety monitoring systems were useful for any organisation with employees that regularly drive. One stakeholder expressed an opinion that it would be good to see such systems used more in 'last mile' delivery models that account for large amounts of work-related driving but are not as heavily scrutinised or regulated as HGVs (e.g. food delivery, parcel carriers, supermarket small trucks and vans).

5.2.3 *Role of leadership, management approach and culture*

Whilst acknowledging the potential benefits listed above, most stakeholders also emphasised a telematics system was a useful tool but not a replacement for good management.

"How you manage it is the most important thing."

Another theme that came through strongly from different stakeholders was that it is important that managers "be realistic about their expectations of drivers". They should show "good leadership that sets clear expectations around safety" and avoid directly or indirectly putting pressure on drivers to do unsafe things to get the job done.

Some offered advice around communication and transparency, such as:

"Communication is key – proactive and early engagement"

"Early engagement with unions"

"Be very open and transparent about objectives with your workforce"

One road safety stakeholder recommended that leaders should aim to influence the culture within the organisation so that drivers are proud of their driving, recognise that it is a real skill and feel like an ambassador for their organisation. "Implement good training, coaching and recognition that helps to reinforce the pride – influence how [drivers] behave, influence through the peer group."

5.2.4 *Policies, procedures and documentation*

The union representative emphasised the importance of proper policies and procedures that clearly laid out the ways that the telematics systems could be used, especially regarding accessing data on individual driver's performance and triggering disciplinary action.

They also emphasised that telematics systems could not replace proper documentation and analysis of incidents. These points were echoed by others.

5.2.5 *Procurement*

A common theme running through stakeholder interviews was stories of organisations procuring systems that:

- don't do what they had been led to believe they would and therefore don't do what they need
- have overly complex data interfaces and require a user to be a skilled database engineer and analyst to distil meaningful information from the system
- produce too much data with no guidance on how to prioritise measures to improve safety
- lack transparency on how algorithms and thresholds work and why they are important.

This has led to under-utilisation of expensive systems and, in some cases, complete disengagement of the workforce and leadership with the system. There were anecdotes of drivers completely ignoring lights on the dashboard because they don't know what they mean and/or they know that no one is monitoring them.

Sheer volume of data was commented on as an issue "They drown under ones and zeroes… getting the data under control is a massive challenge."

Stakeholders recommended organisations should have a clear procurement plan that included:

- what the problem was and what they were looking to achieve
- how much ongoing resource they could put in to managing the system
- how much resource they could put into training and coaching drivers using outputs from the system.

A couple of stakeholders mentioned the complexity of systems and more expressed an opinion that some telematics companies may be selling systems that are overly complex for the needs of businesses, and which make it difficult for end users to interpret and use effectively.

5.2.6 Communication and consultation

Stakeholders were generally in agreement that transparency was important, "ensuring that everyone can see what is going on and why".

One offered the following advice, which was consistent with advice from others:

- "Develop a good strategic internal communications plan.
- Involve health, safety and wellbeing when developing comms plan.
- Involve unions and workforce representatives in the process of designing the system."

5.2.7 System features

5.2.7.1 Indicators

There was some disagreement over which indicators were predictive of risk and useful to target to improve driver safety. There were also some differences in thought on how indicators should be used in coaching and training.

Speed was generally seen as important, but there was some disagreement about how it should be measured. One organisation, for example, struggled with how to manage speeding. They had to make decisions about what kinds of thresholds to set, when strictly, their policy was that no level was acceptable. However, being completely strict led to an overwhelming number of events being triggered. Some interviewees believed that a driver's skill and experience should be considered in judgements about whether speeding was unsafe.

A couple of stakeholders stated that some activities like disobeying the speed limit or contravening a policy such as a prohibition on idling, were indicative of a more general willingness to break rules and take risks, and that it was therefore useful to monitor how often drivers did these things. Similarly, they believed that habitual patterns of harsh braking are an indicator of poor anticipation and possibly other risky habits such as inattention (e.g. mobile phone use) or driving while fatigued. Still others observed apparent correlations between speeding and seemingly unrelated outcomes like low-speed manoeuvre incidents that seemed to be a result of rushing and inattention. Without validation it is not possible to determine whether this is correct.

By contrast, the driver behaviour expert stated that, regarding speed, it should be measured relative to other traffic and according to conditions. In addition, they believed that indicators should be framed in positive terms to motivate improvement. For example, percentage of the drive that was "smooth" rather than counts of harsh braking incidents.

There was a suggestion that some systems may not work particularly well with newer automated braking systems that may inadvertently trigger an 'event' because something in the environment has caused them to brake sharply. There should be a mechanism for the technology provider to update their algorithms and to check and validate data to avoid wasting resources on spurious events. However, if one driver is consistently triggering the AEB then that may indicate an issue (such as a vision problem, fatigue or distraction) that needs to be addressed.

5.2.7.2 Cameras

One of the biggest points of contention is cameras. One interviewee, a fleet risk manager at a major insurer only covers organisations that have telematics systems in place. They stated that 60% of the 120 fleets they insure use cameras. They believe it is important to have a system that allows the manager to analyse the root cause of an incident, and a combination of inward and outward facing cameras are useful for that purpose.

Many of the organisations interviewed mentioned union resistance to driver-facing cameras. The union representative confirmed that the purpose of installing cameras needs to have clear justification and be managed fairly, so as not to encroach on an employee's rights and privacy.

On the other hand, fleet managers were confident that driver facing cameras that record what the driver was doing just prior to a safety event being triggered are invaluable in coaching drivers. As one interviewee put it… "Cameras pointing away from the vehicle have a role in insurance mitigation, but they don't change the behaviour of the driver behind the wheel…" The expert in driver behaviour who was interviewed concurred that driver-facing video of incidents provided very useful material to support one-on-one coaching conversations.

A road safety advocate similarly recounted an anecdote noting that outward and inward facing cameras can tell different stories which are useful for determining the truth in collision situations. More than one interviewee also echoed that driver facing cameras can be invaluable for identifying risky behaviours like not wearing seat belts, use of mobile phones and fatigue, which cannot be picked up by external facing cameras and *g*-force or other sensor measurements alone.

The union representative did however highlight that you can infer from telematics data when the driver was distracted. They also noted concern about reliance on telematics for aspects such as fatigue. It was argued that fatigue should be managed through better regulation and proactive management of driving hours that recognises innate human limitations: "When we have driving regulations that allow drivers to be working extremely longer hours, it is inevitable that they will become tired." This was echoed by insurers, road safety advocates and government official representatives alike.

Organisations should not be encouraging or requiring drivers to drive excessive hours through their scheduling or other work practices. However, inward facing cameras can detect behaviours that other systems cannot, so they can be very useful in the analysis of incidents. They may also be helpful in determining patterns in time when drivers typically start to have drowsiness-related events. This information could assist an organisation to improve their scheduling to avoid pushing their drivers to unsafe limits. If some drivers are having more drowsiness events than others working under the same conditions, it could indicate a need to prompt them to check their sleep habits and/or talk to a health professional to see whether they have a condition that needs to be managed (e.g. sleep apnoea).

However, as previously noted, it is important to have clear policies and procedures to:

- Ensure video footage is not misused
- Protect driver privacy and procedural fairness
- Protect employees from unnecessarily viewing traumatic video content and ensure anyone who does have to view it is given adequate support.

5.2.8 Coaching and feedback

Most stakeholders were strongly of the view that any telematics system needed to be accompanied by good coaching and training, in "a framework of continuous development". However, they differed on what this might entail. For example, some organisations firmly believed in the value of league tables to promote competition between depots etc. One stakeholder expressed concern that "league tables can be a 'blunt stick' to beat the people at the bottom!"

Based on the anecdotes recounted, it seems likely that the culture and management approach to feedback and monitoring tools is equally as important as the feedback mechanism. A league table in one organisation could be used to punish, where in another it could be used to promote friendly competition in a spirit of striving towards improvement.

One stakeholder made the point that fear based appeals are likely to be ineffective. They advocated for more positive approaches like 'getting you home safe and well'. However, being able to have 'difficult conversations' well was an important part of the coaching process.

Some believed in-vehicle alerts and warnings were helpful in quickly alerting drivers when they did something wrong and giving them the opportunity to adjust their behaviour without intensive coaching being required. One expert expressed a firm belief that in-vehicle alerts were unnecessarily distracting, and that coaching was far superior. They also questioned the validity of some of the safety event triggers commonly used in systems and whether they were really measuring things that affected safety.

Distraction is certainly possible, especially if alerts are unreliable or inaccurate, but this needs to be weighed against potential benefits. In some cases, an alert is a more proportionate response than a full coaching session. The interviewee also talked about the potential for 'redlining', an aviation term that describes the practice of pushing systems right to the edge just below where you would trigger a safety event. For example, putting cruise control on in a vehicle just above the speed limit but below where you know the threshold is for triggering a speeding event, and driving like that regardless of the conditions.

Being able to review footage of incidents, both inside and outside the vehicle, was generally seen as very useful for getting to the root cause with drivers and working out how to improve and avoid repeat incidents.

One stakeholder said that coaching does not necessarily need to be done in house, as long as the person doing it has the right 'soft-skills' and doesn't make the driver feel like they are being 'performance-managed'. It could even involve telephone coaching.

5.2.9 Role of other technologies

Some stakeholders highlighted that fleet managers should remember to look for the safest vehicles in their class to protect drivers and other road users. The onus should be on the employer to ensure that vehicles that are appropriate to the job even when operating under the 'gig economy' model. Their concern was that workers are potentially driving older vehicles without the latest safety features (AEB, vehicle stability) which puts the driver, their passenger and other road users at risk.

Other new or developing technologies mentioned that were considered to have potential for impacting on safety included:

- ISA, of the type that involves pedal resistance when speed limit is reached. This makes it obvious when speed limit is reached and difficult to exceed speed limit but doesn't take control away from driver.
- Integration of smart watch technology to monitor vital signs such as pulse with vehicle communications system to enable emergency services to be alerted and ensure prompt medical help in the case of a crash also where the vehicle is advanced enough, to help bring the vehicle to safe stop in a medical event.
- Future combination of telematics and inward facing camera technology with ADAS and facial recognition technology that can allow the vehicle to intervene when the driver is not paying attention to the driving task (e.g. due to distraction or fatigue).

6 Discussion

6.1 Effectiveness

The literature review aimed to examine the effectiveness of vehicle safety monitoring technologies in improving WRRS, as shown through leading indicators, and ultimately measured through lagging indicators. In broad terms, leading indicators included risky driving behaviours that could be monitored through vehicle systems such as speeding, harsh vehicle handling, and moments of drowsiness and distraction. Lagging indicators were measures of road safety outcomes such as crashes, insurance claims and repair costs.

From the literature review, we identified four categories of vehicle technologies that have the potential to improve safety and provide organisations with leading and lagging indicators of risk. These were: telematics systems, Intelligent Speed Assist (ISA), Drowsiness and Distraction Recognition (DDR) systems and collision warning systems. Other technologies also have potential, but these were the ones found to have been evaluated in a fleet context.

Stakeholders were also asked questions about effectiveness and changes in lagging indicators as part of the consultation.

6.1.1 Telematics systems

Of the six studies of telematics systems published since 2011, most found reductions in leading indicators of risk (mainly g-force and speed events) but only one examined crash rates. Quayle and Forder (2008) found a 20% reduction in crashes, but the trial did not have a control group, so cause cannot be definitively attributed to the telematics system. Wouters and Bos (2000) remains the only properly controlled trial published in the last 20 years to have examined effectiveness of telematics systems in reducing crashes in a WRRS context. They found a 20% reduction across all severity levels of crash involvement although with a wide range of results from various fleet types.

This lack of evaluation of effect on crash-involvement and lack of validation of leading indicators is somewhat surprising when you consider the extent of the use of telematics systems in industry. The RAC Business (2016) estimates that two-thirds of UK fleets have invested in some form of telematics in their fleets, and half of these (one third of the total) are using the technology to monitor safety.

Some of the stakeholders interviewed for this study had oversight of the effects of telematics-based systems across organisations (e.g. an insurer and a road safety body that manages a grants program). They had observed reductions in collisions associated with the introduction of telematics systems. The fleet insurer, who only covers organisations that use telematics, stated that their data showed significant overall reductions in the number and severity of claims. However, it is unclear what the mechanism of effect is in such observations, whether it is simply the act of greater monitoring, or the data, management and implementation of the system.

6.1.2 *Intelligent Speed Adaptation and Distraction & Drowsiness Recognition*

There was only one evaluation of an ISA technology that recorded speeding events in a work-related setting (Fitzharris *et al.*, 2011). It was a small study using seven truck drivers, and it was not controlled. It found some reductions in speeds in higher speed zones. The absence of recent ISA studies may simply reflect that standalone ISA devices are not typically set up to report vehicle speeds or violations back to a fleet manager. It may also be the case that speed monitoring and intervention has become more of an in-built feature of vehicles and that speed or speeding is increasingly included in the suite of indicators monitored in telematics systems (rather than a standalone system). Nevertheless, ISA was mentioned by some of the consultation participants as a valuable risk mitigation tool.

The absence of published evaluations of DDR systems in a work-related context is somewhat more surprising, given their increasing popularity in mining settings. There was only one evaluation of a DDR system identified. This was another study by Fitzharris *et al.* (2017) on a much larger sample of trucks in a freight company with a variety of truck types. The study demonstrated a significant effect of intervention when signs of drowsiness were detected. The results relating to type of intervention (feedback) are discussed further below.

There was no system that proactively monitored distraction. Retrospective analysis of the incidence of drowsiness and distraction in safety events are both common features of telematics with cameras. The inclusion of these in telematics systems offers opportunities for coaching and, where consistent patterns are established, to identify where driving hours expectations may be unrealistic.

6.2 Technology-based factors influencing effectiveness

The review further attempted to identify features of the technology that were most effective or presented greater risk through added distraction. Consultation participants were also asked about the how they saw specific features of their technology contributing safety benefits or risks.

Low reliability or accuracy would be expected to have an impact on effectiveness. Perceptions of reliability were measured or specifically commented on in at least two of the studies. Understandably, poor reliability had a negative impact on acceptability of the technology. However, in the Ponte mobile phone blocking study where there was a high organisational commitment to safety, the willingness of the drivers to persist was surprisingly high. Hickman and Hanowski (2011) also note the potential effects of technology problems that may have partly explained poorer results for one of the carriers in their study.

We found no examination of the potentially distracting effects of the technology in the literature on telematics in the context of WRRS. Cognitive psychology tells us there is certainly potential for in-vehicle alerts and communications to draw driver attention away from the driving task, and that the extent of increased risk will depend on how much time the driver spends attending to the signal or warning instead of focusing on the driving task. This will be influenced by how frequently the alerts are triggered and how intense or intrusive they are as well as how much attention and cognitive processing is required from the driver to interpret the meaning of the alert and choose the correct response. The United States' National Highway Traffic Safety Administration (NHTSA) 'Guidelines for reducing visual-manual driver distraction during interactions with integrated, in-vehicle, electronic devices' provide a minimum set of principles which may be helpful in this context NHTSA (2014), although are clearly limited by their relevance to the driving scenario. These are outlined in Figure 6.

1. The driver's eyes should usually be looking at the road ahead
2. The driver should be able to keep at least one hand on the steering wheel while performing a secondary task (both driving related and non-driving related)
3. The distraction induced by any secondary task performed while driving should not exceed that associated with a baseline reference task (manual radio tuning)
4. Any task performed by a driver should be interruptible at any time
5. The driver, not the system/device, should control the pace of task interactions
6. Displays should be easy for the driver to see and content presented should be easily discernible

Figure 6: NHTSA fundamental principles for reducing distraction during interactions with in-vehicle electronic devices

There was no systematic consideration of which features produced the greatest safety benefit either. For example, some systems include cameras that can be used to analyse driver behaviour and record events inside and outside the vehicle around the time of an event. Camera-linked or camera-based systems can measure a wider array of leading indicators (including things like distraction and drowsiness related events). However, there has been no direct comparison of the relative safety outcomes of systems with and without cameras.

Consultation participants agreed that external facing cameras were useful for legal defence purposes, making investigations more efficient and reducing stress on drivers who were 'doing the right thing'. However, they also resulted in employees having access to traumatic video footage that needs to be properly managed. Some consultation participants emphasised that driver-facing cameras that record a short period before and after an event can give supervisors and driver coaches helpful material to use in training and coaching. They argued that this was the most effective way to coach drivers, especially on the effects of things like using a mobile phone or undertaking other tasks while driving, which cannot be detected by other means. Others were concerned that their potential benefits did not outweigh risks such as being misused for covert surveillance, aiding micro-management and unfair treatment of drivers.

The technologies reviewed monitored a range of leading indicators that were presumed to predict crash risk, and for many there is good reason to believe that they should. There are established relationships, for example, between speed and crash risk. However, no study validated these leading indicators by examining their correlation with crash involvement in a work-related driving context. Neither did any of the consultation participants mention validating or examining the efficiencies of their leading indicators in terms of safety outcomes.

It is not possible to put forward any firm conclusions on which indicators are most important for organisations considering a safety monitoring system to choose, or where they should focus their efforts in coaching and training their drivers. This guidance will need to be informed by the organisation's risk assessment combined with some road safety and behaviour change principles. In the absence of clearer evidence, organisations should focus on known risk factors for work related driving such as time pressure, fatigue, distraction, and exposure (mileage) (Grayson & Helman, 2011; Helman, Buttress & Hutchins, 2012).

This insufficiency of evidence has cost and efficiency implications for businesses, as well as safety implications. If businesses are monitoring more indicators than are necessary, and/or coaching their drivers on some indicators that are not predictive of crash involvement, then they are wasting time and resources. Further, any potential distraction or cognitive overload on the driver may be increased by the number of warnings and alerts, so it is important to optimise issuing of warnings and alerts to increase the likelihood that their safety benefit outweighs their potential distraction.

It is likely that much of the research and development of these systems has been done in-house under proprietorial conditions, making for a lack of transparency. Without transparency, there is no opportunity to examine the strength of the evidence, and little information that can be provided to guide fleet consumers in their choices.

6.3 Human-based factors influencing effectiveness

Finally, the review attempted to identify how differences in fleet type and driver group might influence the effectiveness of the technology.

At least one theoretical framework has been proposed to explain the role of organisational context on driver behaviour and safety outcomes, but this has not yet been tested 4.2.1. There were no attempts to directly compare the effects of organisational factors such as leadership or management style, safety culture or safety policies, though more than a handful of studies observed that these factors probably influenced outcomes. There was one study that found significant differences in the effectiveness of telematics systems between fleets, but it was not possible to be certain what particular aspect of the fleet (whether it was the characteristics of the drivers, the organisational culture, the driving environment or a combination of these factors) that was responsible for the differences.

Four studies attempted to compare or test the effects of feedback.

- In-vehicle alerts combined with offline emailed feedback designed using behaviour change principles were more effective than in-vehicle alerts alone (in a telematics system trial with sales drivers).
- Weekly goal setting, combined with an automated written report designed using behaviour change principles, produced a small but significant reduction in speeding violations which returned to baseline after the goal setting sessions stopped (in a speed monitoring trial with community carers).
- Supervisory coaching including goal setting combined with in-vehicle alerts was more effective than in-vehicle alerts alone (in a telematics study with truck drivers) – noting that all drivers were exposed to a safety incident trend chart reflecting their depot's performance, displayed publicly at their depot.

- In-vehicle warnings for drowsiness were associated with significant reductions in fatigue events, which were further reduced by the driver's supervisor calling the driver when an event was detected (in a drowsiness detection trial with truck drivers).

This suggests that (1) feedback that involves coaching (goal setting and feedback) with a supervisor or other authoritative figure is more effective than in-vehicle alerts alone; (2) that in some circumstances, in-vehicle alerts alone may not be more effective than general feedback at the site- or company-level. However, these results may be specific to the organisations and driving contexts in which the feedback and technology was trialled. For example, while it might be proportionate and effective for a supervisor to call and discuss options with a long-haul truck driver who is having microsleeps, it would potentially be dangerous to intervene like this every time that a driver in city traffic recorded a sharp braking event. This speaks to one of the principles proposed by Horrey et al. (2012, p.53): "The intrusiveness of feedback should be commensurate with the urgency of the information to be conveyed".

Most consultation participants agreed that a positive and supportive approach to coaching and feedback for drivers was important, but there were differences in how this was done. Some used driver trainers, others used managers, and some mentioned the potential for using external coaching and training services to deliver feedback, coaching and/or training. There was some disagreement about the role of in-vehicle alerts, with some seeing them as an efficient way to quickly address some issues and others seeing them as an unnecessary distraction that only taught drivers to avoid setting off an alarm and did not really train them to be better drivers. Guidance on this, therefore, needs to be based on principles of organisational psychology and behaviour change.

No study was found that attempted to directly compare effects of the technology on different driver groups (e.g. young drivers, older drivers etc.). Studies are generally conducted in the fleets that are most likely to have the technology installed, in one fleet or a small number of fleets at a time. This has led to a predominance of studying one demographic group (generally older males) and fleet type (often trucks) in the work-related driving context. This limits our ability to judge fleets and driving conditions in which the technology is likely to be effective.

There has been little attention paid to a growing fleet of drivers and riders in the gig economy who are predominantly young and potentially being exposed to excessive hours of work. From a technology point of view, there is an argument that organisations that employ these drivers and riders should be improving app design to reduce inadvertent incentives to engage in risky driving and riding behaviours such as distracted driving, speeding and drowsy driving.

6.4 Evaluation of the quality of evidence

Limitations of the research into the effectiveness of telematics were noted in section 4.1. They centred around lack of transparency and validation of indicators and impact on safety outcomes. Those studies that do evaluate impact generally do not use control groups (making it difficult to ascertain that any change in safety outcomes was attributable to the system and not some other change); do not select participants at random (introducing bias) and tend to involve a single homogeneous cohort (making generalisation of findings to other contexts challenging). They tend to evaluate a single device with multiple features but do not compare which features or indicators have a greater impact on safety, and they do not generally provide enough information on how feedback is provided to drivers to allow insights into what is the most effective and efficient way to promote change.

There have been some efforts to redress this, and this is not intended as a criticism of those who have contributed to what evidence is available. There are significant challenges to designing and implementing robust well-controlled trials in real-world commercial environments. However, it is in the interests of industry to ensure that they are getting the best safety outcomes from their investment and that they are not wasting money on ineffective or inefficient systems.

6.5 Implementation challenges and lessons learned from the consultation

Some implementation challenges were noted in the literature, but most observations of implementation challenges come from the consultation.

Organisations that implement telematics systems in their fleets may be very large and have vehicles spread across multiple sites. This presents a challenge for communication with drivers and managers. Those who had successfully implemented systems talked about having strong communications plans that enabled them to cascade consistent information out to drivers through their line management and using existing channels of communication. Some talked of sharing video clips to explain how the system would work and what it would be used for.

Distrust and concerns about being constantly monitored was a challenge that most seemed to overcome through strong communication and consultation, including with unions and staff associations. A few mentioned a strategy of piloting the system in one depot that had a supportive manager in order to test the system and address issues before attempting to roll the system out to the whole organisation.

A common theme was of systems that measure many indicators and produce large volumes of data. This combined with a high degree of variability in the quality of guidance on which indicators to monitor to get insights into safety has an impact on effectiveness and efficiency. The consultation found themes of organisations being overwhelmed with data that they could not get useful insights from, and in several cases, resulted in the organisation having to pay somebody else to analyse data or design a bespoke reporting system.

6.6 Summary

Based on behavioural principles, well designed telematics-based safety monitoring systems should have significant safety benefits. There is some indication from the research that they may reduce fleet crash involvement. This indication is supported by observations from insurers, road safety bodies and organisations that have implemented telematics.

However, the level of effectiveness is not firmly established despite more than two decades of use. In terms of measurable safety outcomes, there remain gaps in evidence around:

- Which telematics measures of leading indicators are best predictors of crash risk beyond known general principles (i.e. speed, distraction and impairment)?

- What is the minimum number and optimum mix of indicators that need to be measured?
- How best to provide feedback to drivers?
- What role do organisational factors such as leadership, culture and policies play in the effectiveness of technologies?
- What role does the driving environment and nature of the driving task play in the need for different types of support from technologies and supervisors.

In providing guidance for the update of INDG382, it will therefore be necessary to rely significantly on established organisational psychology and behaviour change principles, and the insights offered from stakeholders and fleet safety managers. Guidance on indicators will rely on well-established relationships between driver behaviour, vehicle dynamics and crash risk such as speed, distraction and impairment (e.g. fatigue and sleepiness).

7 Conclusions

Section 7.1 to 7.5 provide full conclusions and points that could be considered for the INDG update. Section 7.6 provides an overarching summary for direct inclusion.

7.1 Indicators and features

Based on psychological principles, road safety fundamentals, and input from the review and consultation, the following minimum list of indicators is suggested:

- speed (preferably in relation to the speed limit and, if possible, compared with average speeds of other vehicles on the same stretch of road at that time of day and in the same conditions)
- harsh braking and swerving (as a possible indicator of lack of attention, anticipation and/or driving too fast for conditions)
- hard acceleration and cornering (as a possible indicator of unnecessarily aggressive driving style)

Based on behaviour change principles, it may be better to present reports back to drivers with these indicators framed positively (for example, percentage of the drive that was smooth, in control, and at an appropriate speed). Organisations should focus on coaching (goal setting and feedback), as this is likely to be more effective than in-vehicle alerts alone. Simply putting in a system and doing nothing with the outputs will result in no change in driver behaviour, and there is some evidence that initial improvements from relying solely on in-vehicle alerts may diminish over time.

Organisations should review the indicators that they monitor on a regular basis to identify which are related to changes in safety outcomes (from near misses to collisions). They should aim to monitor the smallest number of indicators that give the greatest insights into driver behaviour and the biggest influence on safety outcomes. Where possible, they should work with their workforce and their telematics provider to ensure that reporting thresholds for safety events are set at a level where they can have an impact on safety outcomes without causing undue distraction or overwhelming drivers, their trainers and managers with data and alerts.

Organisations should also consider intelligent speed assist (ISA) options that intervene to prevent speeding as there is good evidence that they reduce crash risk.

Where fatigue is a significant risk, drowsiness detection (based on face and eye movements) is also very promising, with the caveat that organisations should not come to rely on such technology in place of good workload and shift planning.

Driver facing sensor triggered camera systems may be useful for coaching, especially if there are issues with driver distraction or drivers failing to wear seatbelts. Organisations should be careful to ensure that their policies (for example, requiring drivers to answer phone calls while driving) do not conflict with such systems. They should also ensure that they have a good coaching system in place that makes good use of the data collected.

If organisations install outward facing cameras, they should have well documented policies and procedures for handling the data, including to protect privacy of people in the footage and protect staff from unnecessary exposure to traumatic video material. Where an organisation has the resources to support their proper use, it is likely that driver facing cameras could have a safety benefit. To test whether cameras are helpful in addressing risks, organisations could first trial such systems in one depot or in one team to allow them to evaluate their effects, address any issues and use the opportunity to fine tune policy and procedures related to fair use, monitoring and access as well as coaching.

7.2 Plan, Do, Check , Act

INDG382 uses the ‘Plan, Do, Check, Act’ framework to provide guidance to organisations. It is a model for continuous improvement. The approach is:

1. Plan: Identify organisation goals and develop/review a plan to achieved desired goals. Identify obstacles and how to tackle them. Set clear action plans and measurables.
2. Do: Implement the plan developed in Step 1 to test its feasibility and effectiveness. Delegate the work. Take note of problems encountered and how they were dealt with. Collect data.
3. Check: Analyse the data collected. Measure how you are performing.
4. Act: Review your performance. Identify what was learnt. Decide what works and what needs to be improved. Review the plan and repeat from Step 1.

The literature suggests that for a safety technology to be effective and sustainable:

- It needs to clearly address a well-defined risk.
- The technology’s purpose and how it will be used needs to be clear to the system users including drivers.
- Indicators need to be chosen that will enable the organisation to track progress in managing that risk.
- Outputs from the system need to be clearly related to the risk that is being managed.
- Outputs need to be easy for drivers, and anyone involved in managing or coaching them, to access and interpret.
- Implementation and ongoing maintenance need to be within the financial means and human resource capacity of the organisation.

The evidence from this review and consultation suggest the following are ways to get the best safety benefits from vehicle telematics.

PLAN

- Be clear about the problem that you are trying to address. Assess the level and types of road risk that your organisation experiences and consider how well a telematics system or other monitoring technology might address these.
- Assess your organisation’s capacity and capability to implement, monitor and manage telematics-based systems and monitoring technologies.

- Ensure you have resourcing for ongoing monitoring of system outputs and coaching of drivers.
- Be transparent. Develop a clear communications plan to support your drivers to understand what you are doing and why.
- If possible, involve drivers and managers in the choice, design and/or set up of the system.
- Develop a training and coaching plan. Consider whether feedback and coaching would be more effective if it was delivered by a trainer or coach independent of line management.
- Review your managing occupational road risk (MORR) policy and document how the system will be used to support managing road risk in your organisation, including who can access the data and for what purposes.
- If you are collecting video footage of drivers, ensure that you have clear guidance in your policy about how, when and for what purpose these data can be accessed.
- If you are collecting external video footage, ensure you have a plan for how you will ensure that staff are not unnecessarily exposed to traumatic content.
- Ensure you have secure data storage and a data management plan for any data of a private or sensitive nature.
- Develop a plan for how you are going to measure success or return on your investment.

DO

- Follow your procurement, communication and implementation plans.
- If possible, trial new systems in stages that allow you to test them and make changes and improvements before committing to a full rollout.
- Invest in the system that gives you what you need – is it important to you to be able to access and analyse raw data, or do you want a system that provides automated reports on a core set of indicators?
- When procuring new vehicles, remember to consider passive technology and ADAS that require no monitoring (beyond normal servicing and repairs) but will protect drivers even when they make mistakes.

CHECK

- Monitor trends in leading and lagging indicators, and look for patterns and relationships between the leading and lagging indicators to validate the predictive capability.
- Aim to monitor the smallest number of indicators that give the greatest insights into driver behaviour and safety outcomes. Stop using indicators that are not having a demonstrable impact or are not useful in coaching drivers.
- Get feedback from drivers, coaches/trainers and managers on how the system is working for them. Is it addressing the problem that you brought it in to address? Are

managers and supervisors getting the information that they need out of it? Is it reliable? Is it causing any distractions or problems?

ACT

- Be efficient. Remove any indicators from your reporting that are not giving useful insights and/or not being used.
- Make changes in response to feedback from drivers and managers that improve the benefits that you get out of the system.

7.3 Procurement of technology

Good procurement is a key part of ensuring that the telematics system is a good fit for the business needs.

- Be clear on the risks that you are trying to address and the resources that you have available to address them before speaking to salespeople. Talk to more than one supplier. Ask them:
    - What evidence is there that monitoring this set of indicators is likely to result in fewer crash involvements in my fleet?
    - What data and reporting outputs will the system provide?
    - What support can you provide for training and coaching drivers? Will it need to be customised for my organisation?

7.4 Gig economy workers

If an organisation provides an app that its drivers and riders must rely on to do their work, then the organisation is responsible for ensuring that the app can be used safely. It is reasonable to expect that the app should not create incentives to drive or ride in a way that increases the risk of harm to the worker or others.

As part of their risk assessment, organisations that contract drivers through a ‘gig economy’ model need to review the safety impacts of the technology through which they manage the distribution of work. Organisations operating in the gig economy usually put significant effort into the design of their app interfaces to influence consumer behaviour. It is therefore plausible that they could put similar effort into designing their apps to facilitate safer driving and riding. From a vehicle technology perspective, organisations should:

- Examine the influence of their app design on driver and rider behaviours including speeding, fatigued and distracted driving, and revise the design.
- Examine how apps and data linkages could be used to monitor driver workload and working hours to minimise the risk of drivers and riders exceeding maximum working hours.
- Consider the potential to use data gathered through the app to provide feedback about driving/riding performance and encourage drivers and riders to take adequate breaks and rest periods.

- Consider providing information to drivers on how to choose safer vehicles and manage distractions from technology.

7.5 Resources to assist in choosing safer vehicles and technologies

INDG382 currently has a section titled ‘Find out more’. This section already includes useful resources such as the *RoSPA* and *Driving for Better Business* websites. It may be worth considering revision of this list to include other resources such as:

- Advice on how to procure vehicles with the best combination of currently available passive and active safety technologies, including safety monitoring systems. *EuroNCAP* provides standardised ratings of the safety of vehicles, including the ability to filter by specific driver assistance systems such as AEB or ISA.
  https://www.euroncap.com/en
- Another website that provides helpful guidance regarding managing occupational road risk, including advice on vehicle technologies and telematics, is the Scottish Occupational Road Safety Alliance (ScORSA).
  https://www.scorsa.org.uk/
- The revised General Safety Regulation (EU) 2019/2144, coming into force in July 2022 for new vehicle types, improves safety for motorists and vulnerable road users, such as pedestrians and cyclists. It will gradually introduce advanced safety systems such as: intelligent speed assistance; alcohol interlock installation facilitation; driver drowsiness and attention warning; advanced driver distraction warning; emergency stop signal; reversing detection; and event data recorders.
  https://ec.europa.eu/growth/sectors/automotive/safety_en

7.6 Recommended addition to INDG382

Based on the conclusions above, we recommended this addition to the bottom of the current page 4 in INDG382.

“The Use of Vehicle Safety Monitoring Technology to Manage Risk

Vehicle safety monitoring technologies ('telematics') can help you monitor indicators of risky driver behaviours (e.g. excessive speed, harsh or erratic driving, distraction and drowsy driving). Things to consider in choosing a system:

- Outputs from the system need to be clearly related to the risk that is being managed. You should monitor the smallest number of indicators that will enable you to effectively manage your risks. A good minimum list would include speed, harsh braking and acceleration, swerving and cornering.
- Management and coaching feedback are a critical part of the system. Organisations should not rely solely on in-vehicle feedback. Choose a system that does not give excessive in-vehicle feedback that may be distracting for drivers.
- Intelligent Speed Assist (ISA) technologies are particularly effective and should be prioritised when choosing a system.

- Where fatigue is a potential risk, drowsiness detection technology (which may require cameras) is likely to be effective, although this should not replace fatigue management polices such as proper shift scheduling.
- Any system should be easy for drivers and anyone responsible for coaching their driving to use, access data from and interpret.
- Organisations that contract drivers through a 'gig economy' model should recognise their responsibilities in managing WRRS and ensuring the apps they provide to manage the distribution of work do not create additional risk.

Leadership and management

- As with any business improvement process it is essential that leaders at board and executive level demonstrate commitment to the desired outcomes. This should include clear communication, and embedding the safety and business outcomes being targeted for improvement from the introduction of telematics systems into individual objectives.
- Any telematics system should be implemented using a Plan, Do, Check, Act approach, supported by clear documented policies and procedures."

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Appendix A Literature search method

A.1 Search criteria

For the literature review, a list of search terms was first developed that were informed directly by the research objectives as stated above. This focused the search to identify information on the use of monitoring technology in work-related driving. These terms were used in combination with each other and 'wildcard' searches were used to capture variations in particular terms (e.g. mitigat* would capture mitigate, mitigates, mitigated, mitigation and mitigating).

The final set of search terms can be seen in Table 3. The first and second level search terms were expected to be the most fruitful when conducting the search. These terms retrieved broad results including studies on non-work-related driving, eco-friendly and cost-efficient vehicular technology, and review of management styles in work-related road safety. Even after incorporating the third level search terms to refine the results, more relevant literature was obtained by the inclusion of a fourth level.

Table 3: List of search terms

(1st Level Search Terms)		(2nd Level Search Terms)		(3rd Level Search Terms)		(4th Level Search Terms)
Driver		"Work-related"		"Vehicle technology"		Safe*
Driving		"Gig economy"		Telematics		Risk*
		Fleet		"Monitoring device"		Hazard*
		"Grey fleet"		"Monitoring system"		Effect*
		Professional		"Warning system"		Evaluat*
		Occupational		Event data recorder		Eviden*
		"Work-related Road Safety"		In-vehicle data recorder		Distract*
		WRRS		"intelligent speed assist"		Mitigat*
		"Managing Occupational Road Risk"		"autonomous emergency braking"		Accident*
	AND	MORR	AND	"reversing detection"	AND	Collision*
		"business-related"		"lane keep assist"		Injur*
						Speed*
						Brake*
						Steer*
						Interven*
						Avoid*
						Feedback
						"Visual feedback"
						"Audio feedback"
						"Haptic feedback"
						behaviour
						fatigue

A.2 Assessment of quality and relevance

In order to ensure that only literature of sufficient quality and relevance is included in the review, specific criteria were used to assess the suitability of the identified literature. The criteria were applied twice, once during an initial review of abstracts and again during the full-text review. A shortlist of papers was identified by reviewing abstracts. The full texts were sourced for a full review.

Each document identified was given a score for relevance (e.g. how useful it is to answer the research questions), and quality (e.g. whether it details a robust scientific study). The timeliness of the evidence (e.g. does it reflect what is current) was also considered, although not formally scored. Some older research was included if it was very high quality due to the small numbers of high-quality studies available with relevance to certain specific questions. The final criteria can be seen in Table 1. This scoring system allowed us to determine the criteria for inclusion. We did not include any literature with a score of 1 on any criterion in the review.

Table 1: Proposed inclusion criteria

	Score = 1	Score = 2	Score = 3
Relevance	Not relevant to the objectives of the project	Some indirect relevance to the objectives of the review (e.g. research regarding similar technology)	Directly relevant to the objectives of the review (i.e. research which evaluates the impact of work-related technology on safety, or plausible proxy measure)
Quality	Non-scientific study with demonstrably poor method	Non-peer reviewed scientific study lacking sufficient detail to demonstrate a fully robust method, but appearing to have some credibility	Peer-reviewed scientific study with at least an assessment of change after the use of monitoring technology, and accounting for confounding variables through appropriate methods

A.3 In-depth review of full text

In addition to the shortlisted papers, the reference lists of these documents were also examined to identify whether any further literature can be obtained. This technique is known as ‘snowballing’.

Once the full texts of the shortlisted papers were obtained, the literature was reviewed in full and the key information was collated in a research matrix. Each source was represented in a row in the matrix, and the method, findings and conclusions of the research summarised in columns. The inclusion criteria presented in Table 1 were applied and only those scoring 2 or 3 on each criterion were included in the full review and report. This resulted in further exclusions and identification of additional references. The outputs of this in-depth review and exclusion of literature are shown in Figure 2. We finally included 36 studies in the report.

Assisting the update of INDG382: Vehicle technologies

Driving is one of the riskiest work tasks, accounting for around one third of fatal crashes in the UK. Organisations are expected to manage work-related road safety (WRRS) in the same way that they manage other health and safety risks. The Health and Safety Executive (HSE) and Department for Transport (DFT) issue joint guidance on this in INDG382 ‘Driving at work: managing work-related road safety’.

HSE and DFT were seeking to update INDG382 to include reference to vehicle safety technologies that could enable employers to monitor safety related events or driver behaviours to support learning and safety improvements. They commissioned TRL to conduct: (1) a literature review focused on evaluations of the impact of these technologies on work-related road safety (specifically, crash risk) and (2) in-depth interviews with eight representatives of organisations who had implemented technology-based safety monitoring in their fleet and 11 stakeholders and experts who provided further insights into factors affecting successful implementation.

Telematics systems, drowsiness and distraction recognition systems and collision warning systems have significant potential safety benefits, but rigorous published evaluation of safety-focused telematics in the fleet context is limited. There is good evidence for the safety benefits of intelligent speed assist in private and fleet vehicles.

Successful implementation relies on procuring systems that match needs, managing the potential for data to overwhelm and embedding monitoring and driver feedback within good management systems and strong safety leadership. This report provides recommendations for updating guidance for organisations considering implementing vehicle safety monitoring technologies (telematics).

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