in the heavy vehicle national law and all have extended liability offences attached to them. It is less clear how a party in the chain might influence driver distraction. The ways in which supply chain parties could prompt driver distraction – for example by phoning drivers to check on their whereabouts and estimated arrival time – are fairly easily managed by not disclosing driver contact details.

Further, it may be that distraction is assumed to be a *symptom* of driver fatigue, rather than a distinct behavioural category in its own right. But it may also be possible that distraction, as a form of stimulation, could counter fatigue. For example, anecdotal evidence suggests that interacting with other drivers on the CB radio is sometimes used by drivers to revive themselves. Toll NQX welcomes further policy investigation of the role of driver distraction in the heavy vehicle policy context.

Into the future, in-truck cameras could be adapted to play a role in mass, distance, location charging; if indeed that is the charging option pursued by government. Cameras could conceivably be configured to record not just the driver in-cab and the stretch of road immediately in front of the windscreen, but the road beneath the vehicle. Coupled with vehicle suspension data this footage could be relayed to the appropriate road funding agency to prompt road resurfacing or other mitigation. In the absence of an infrastructure response, road condition could be used as a factor in variable registration costs (harsher conditions cause greater wear and tear on vehicles and therefore impact productivity due to extra servicing requirements). Toll NQX will continue to explore the possibilities of in-truck cameras and share its experiences with policy makers.

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Driver State Sensing (DSS) machines at Toll Resources and Government Logistics

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Information based on a symposium presentation facilitated by Sarah Jones at the Australasian Road Safety Conference (ARSC 2015), 14-16 October, Gold Coast, Australia

Introduction

Toll Resources and Government Logistics (TRGL) is a business unit within Toll Group that specialises in logistics services to the oil and gas, mining, and government and defence sectors in Australia, Asia and Africa. It is a diverse and often high-risk enterprise that transports dangerous goods on public roads and on private roads owned and/or managed by mine sites. Goods carted include fuel, security sensitive ammonium nitrate, coal, iron ore, class 1 explosives, zinc and lead. Unsurprisingly, given the nature of the goods carted, TRGL operates in a highly regulated environment. A plethora of laws and regulations can apply to a single transport task, including the heavy vehicle national law, dangerous goods legislation, workplace health and safety laws and mining-specific legislation such as the Mining and Quarrying Safety and Health Act and the Coal Mining Safety and Health Act.

The incident at Mona Vale in New South Wales in 2013 illustrates the salutary importance of risk management in dangerous goods cartage. That incident left two people dead and five injured, caused a 60% reduction in the share price on the Australian Stock Exchange for the company concerned (McAleese Transport), cost 540 people their jobs and led to more than 300 vehicles in the fleet being grounded (Hassall, 2014). It was as a direct result of this incident that Australian Transport Ministers instigated the roadworthiness projects currently being managed by the National Transport Commission (NTC) and the National Heavy Vehicle Regulator (NHVR) (NTC, 2014).

What is perhaps less commonly known is the extent to which mindfulness of risk motivates dangerous goods customers to demand change and innovation from their carriers as a condition of work. This is chain of responsibility in action: customers using their influence to drive safety and compliance. For example, it is standard for fuel suppliers such as Shell to stipulate a maximum age for vehicles carting their goods, thus ensuring that the fleet is equipped with the most modern designs, standards and technologies. This paper discusses how customer concerns influenced TRGL to explore technological solutions to fatigue management. Although the system TRGL deployed also has a distraction management function, this paper addresses only fatigue management.

Managing fatigue

The risk posed by fatigued drivers is well understood in the road safety literature and is reflected in laws applying to heavy vehicles. Fatigue is estimated to be the predominant cause of 12% of serious injury crashes involving heavy vehicles (NTI, 2013). Not sleeping for more than seventeen hours can have effects on the human body similar to a blood alcohol concentration of 0.05. Not sleeping for more than twenty four hours can have effects on the human body similar to a blood alcohol concentration of 0.10 (Williamson, Feyer, Friswell and Finlay-Brown, 2000). The literature suggests that commercial vehicle drivers sleep, on average five to 6.5 hours per night – well below the recommended eight hours (Sharwood, Elkington, Stevenson and Wong, 2011, p. 25). Further, commercial vehicle drivers would appear to have a higher prevalence of sleep apnoea than the general population and 'it may be expected that the crash risk is greater in a CMV [commercial motor vehicle-driver] population [although] this has not been empirically demonstrated' (Sharwood, Elkington, Stevenson and Wong, 2011, p.25).

Managing fatigue is therefore vital for safe driving. There are essentially two components to fatigue management from a legal and compliance perspective: prescribed work and rest hours, and fitness to drive. The first component is relatively easily managed. TRGL uses the technologies Trimble and MT Data in some parts of the business to monitor work and rest hours in real time. It can therefore respond promptly in a situation where a driver is at risk of exceeding allowable work hours. National work diaries are also audited retrospectively to ensure compliance with the heavy vehicle national law.

'Fitness for duty' is a much more difficult proposition. A driver could be compliant with all work and rest hour regulations but still be impaired by fatigue. However, because there is no objective test for fatigue (such as there is for blood alcohol concentration), recognising and managing fatigue is not an exact science. It is further complicated by the fact that 'fatigued people are unaware that they are not functioning as well or as safely as they would if they were not fatigued' (NTC, 2007). For this reason, standards and processes are required to supplement, and even veto, the drivers' judgement about their fitness.

In 2011 TRGL's mining services business faced a serious dilemma. One of its contracts was at risk because of two vehicle rollovers in quick succession. Fortunately, no one was hurt in the rollovers, but the risk was unacceptable. Fatigue was suspected in both cases and TRGL set about investigating how or if technology might assist in managing the risk.

Driver state sensing (DSS) pilot program at German Creek

In July 2011 TRGL began a trial of 'driver state sensing' (DSS) machines designed by the company Seeing Machines at its German Creek operation in Queensland. At the time Toll utilised twenty heavy vehicles to haul coal from production sites to the wash plant. The vehicles worked in twelve hour shifts, one shift being from 6am to 6pm and the other from 6pm to 6am. DSS machines are in-vehicle systems that capture eye-lid and head motion through sensitive cameras mounted at eye-level in the vehicle. The fact that the driver is not required to wear or affix equipment, such as glasses, was a key factor in selecting this technology for trial. Figure 1 below illustrates the portion of the driver's face that the initial DSS prototype captured:

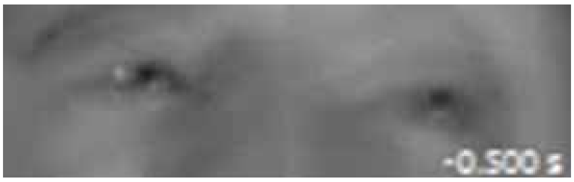

Figure 1. Footage capture by DSS version 1

The DSS works on the premise that a micro-sleep is a symptom of fatigue detectable by the camera. The obvious danger of a micro-sleep is that a vehicle may travel a considerable distance with a driver in a semi-conscious state and therefore not in full control of the vehicle. Table 1 below illustrates how far a heavy vehicle can travel at various speeds in a two second period:

Travel Speed	Distraction Time	Distance Travelled (metres)
40 km/h	2 seconds	22.22
50 km/h	2 seconds	27.78
60 km/h	2 seconds	33.33
80 km/h	2 seconds	44.44
100 km/h	2 seconds	55.56

Table 1. Distance travelled in two seconds at various speeds

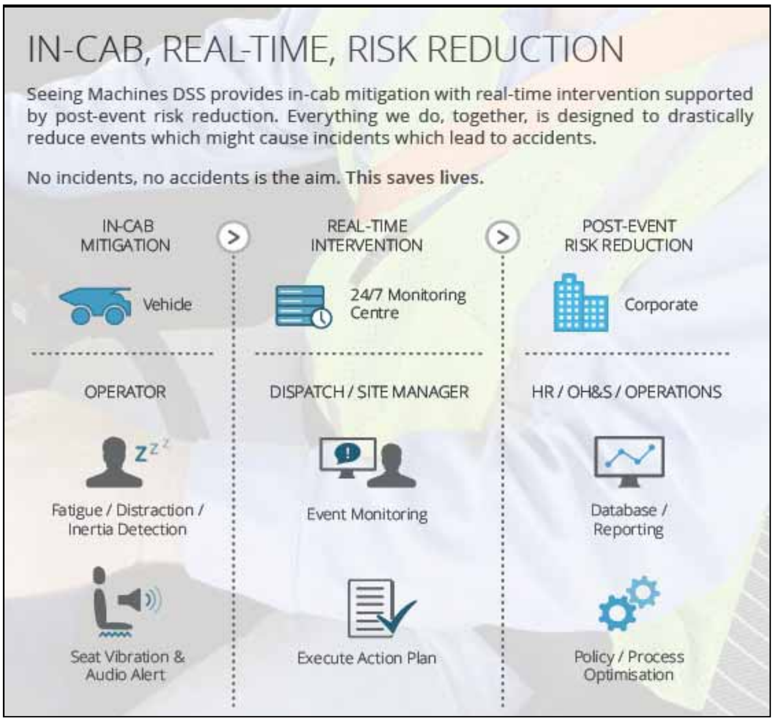

Figure 2. Components of Driver State Sensing (DSS) system

How the DSS system works

There are three components to the driver state sensing system: (1) in-cab mitigation, (2) real-time intervention and (3) post-event reduction. In-cab mitigation occurs when the system detects what might be a 'fatigue event', defined as an eye closure of 1.5 seconds or more while the vehicle is travelling over 5km/hour. The fatigue event triggers an aural alarm and vibrations in the seat.

At the same time, video footage of the incident is captured and relayed to a monitoring team. The team review the footage and 'weed out' false positives, i.e. footage that is not indicative of fatigue. For example, the camera sometimes interprets the glare from spectacles, reflection interference from a high-vis vest and even designs on eye-wear as 'pupils'. The camera may also interpret glances to the left and right as the driver checks for oncoming vehicles as fatigue events if the glance is sustained for more than 1.5 seconds.

Where the footage is determined to be a genuine fatigue event, it is categorised as follows:

- Fatigue mitigation: occurs when the eyes are closed in a controlled manner, for example to rest the eyes
- Drowsiness: occurs when the driver appears to have some awareness of his/her fatigue and is visibly fighting it, for example by resisting eye closure and;
- Microsleep: which occurs when the driver's eyelids close involuntarily, often accompanied by an eye or head roll.

Once categorised, site supervisors are alerted to the fatigue event by the monitoring team. The supervisor will respond according to the fatigue management plan for the site. The response might include a discussion with the driver about his/her current state and fitness to drive. As a result of the discussion the driver may self-select out of the shift or the supervisor may make that determination. Alternatively, the driver may elect to take a rest break. The footage is also reviewed by TRGL's compliance manager who has the authority to halt the vehicle and remove a driver from shift if he has concerns about fitness for duty. In all instances across all TRGL sites where three fatigue events occur in a single shift, the driver is stood down for the remainder of the shift, regardless of the driver's personal assessment of their fatigue risk.

The third component of the system involves post-event follow-up whereby the monitoring team contact the site supervisor to ensure that intervention occurred and to discuss mitigations enacted. The monitoring team also collate and analyse the data produced by the system to determine trends and issues. This data is then shared with TRGL management and with the system providers to inform ongoing refinement of the technology and the supporting policy. Figure two below illustrates the components of the DSS system.

Results

When the initial DSS pilot was run at German Creek, baseline data was collected to provide a point of comparison for fatigue events pre and post implementation. In the first phase of the pilot, the cameras were enabled but no other action taken. So, if a fatigue event was detected it was recorded but the driver and supervisor were not alerted and no follow-up action was taken. In the second phase, the in-cab alerts were enabled and the fatigue management plan initiated.

As indicated by Figure 3 below, fatigue events fell by 82% when the system was fully initiated.

This data needs to be interpreted with extreme caution. It is certainly not the case that the reduction in fatigue events represents a commensurate reduction in actual fatigue. Part of the reason the fatigue events fell so radically was that once the complete system was activated the monitoring team filtered out false positives. The baseline data includes everything that the camera *interpreted* as a fatigue event; the post-implementation data has the benefit of human judgement about whether the footage was likely to reflect *actual* fatigue.

At the same time as the DSS system was enabled, TRGL ramped-up its efforts to educate drivers about the risks of driving while impaired by fatigue. The business featured more information about health and wellbeing (including the importance of diet, exercise and sleep) in its toolboxing sessions. It is therefore difficult to disaggregate exactly what proportion of the reduction in fatigue events is attributable to the DSS system and what to lifestyle changes instigated by drivers as a result of these sessions and other information. In retrospect, it would have been useful to survey drivers on their perceived levels of fatigue (using an instrument such as the Epworth scale) and perceived importance of managing fatigue pre and post implementation.

Despite these methodological limitations, TRGL was confident that the pilot (which incurred capital costs of around $270,000) was having a positive impact on fatigue management and elected to continue and extend its use. To date 188 vehicles have been DSS-enabled within the TRGL business unit. Ongoing refinement of the technology and volume-based purchasing has resulted in a significant price reduction. TRGL incurred additional costs from late 2013 when it assumed the monitoring function from Seeing Machines and initiated 24/7 monitoring from its Brisbane.

Perhaps the most significant result achieved to date is that no operational TRGL vehicle equipped with DSS has experienced a rollover. TRGL is therefore confident that there is a correlation between its deployment of the DSS system and the elimination of rollovers. At the same time, Toll Group has intensified its efforts to eliminate rollovers across the entire business through adopting a zero target. Toolboxing, training and information bulletins are utilised to keep awareness of the risk of rollovers high. Again, this makes it difficult to disaggregate the impact of the DSS system from other initiatives and to attribute causal relationships.

Challenges

Technology cannot yet (and may never) provide an objective measure of fatigue in the way that a breathalyser can determine blood alcohol content or a speed camera can detect vehicle speed. Systems like DSS provide evidence of human behaviours that *might* indicate driver fatigue. The system has been progressively refined over the four years

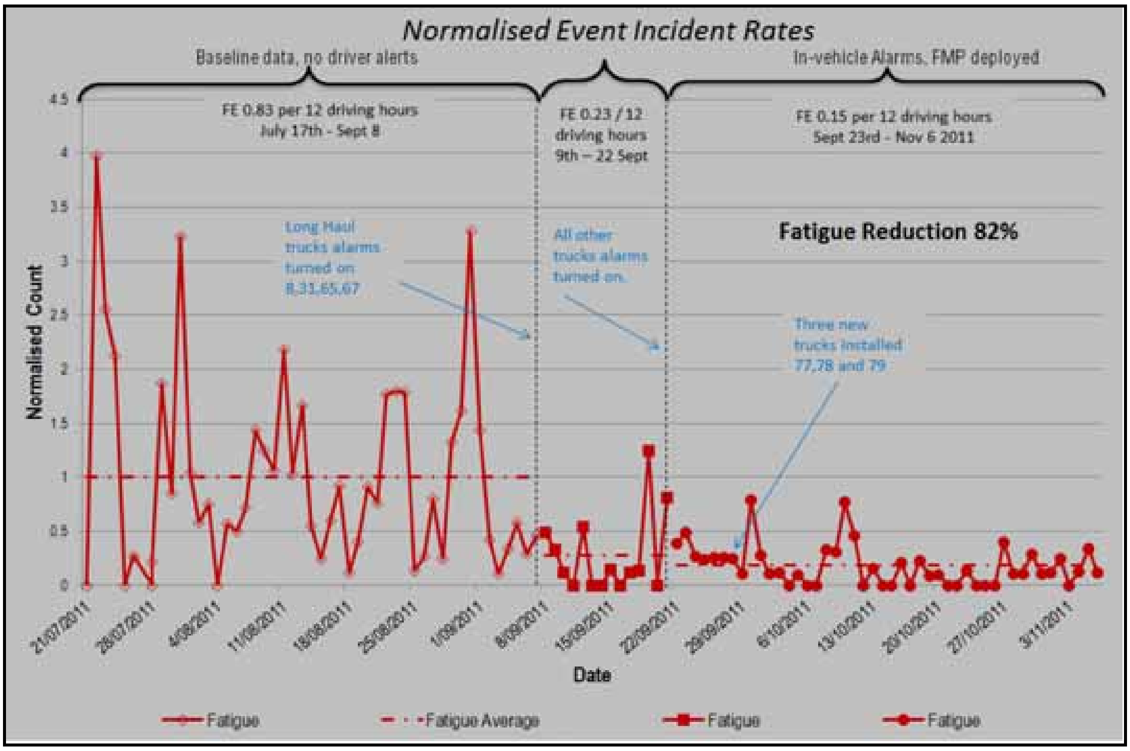

Figure 3. Fatigue events at German Creek July 2011 to September 2011

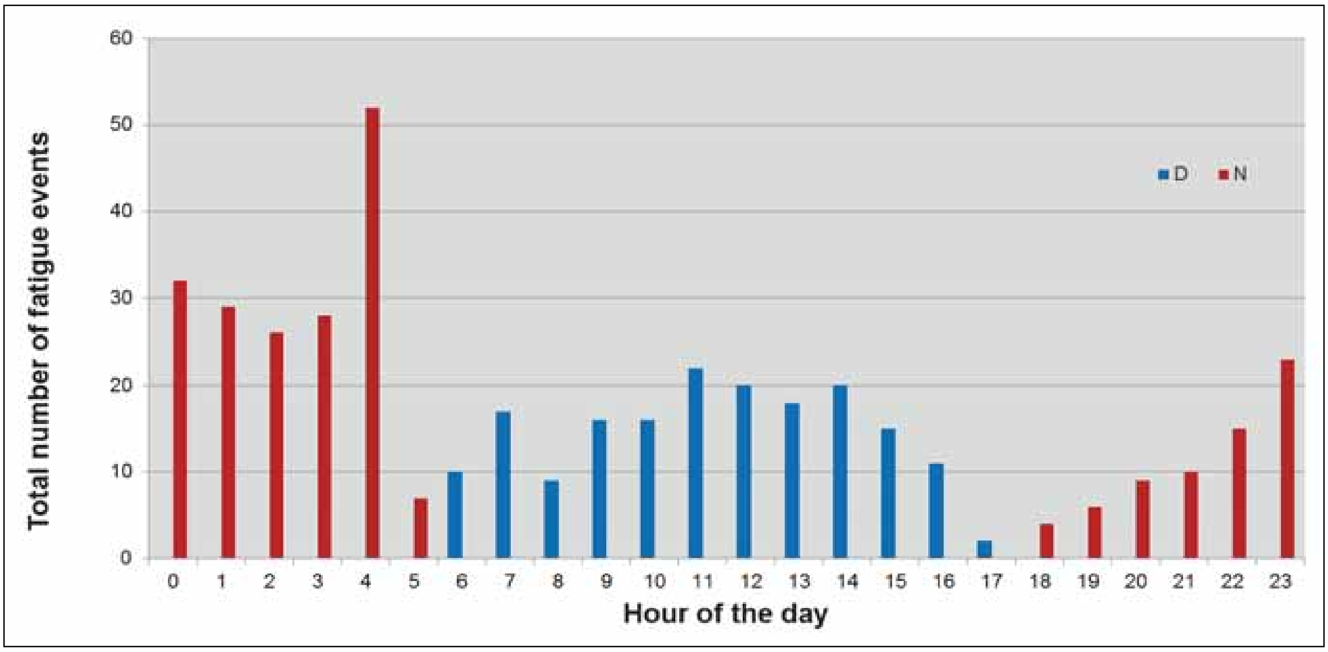

Figure 4. Fatigue events by time of day (24 hour clock)

since the initial pilot and is now significantly more accurate at detecting true positives. Rather than capturing only the eyes, the system now captures the entire face through 75 'mapping' points. It has become smarter at recognising an individual's baseline 'normal' and is more likely to detect genuine fatigue events as confirmed by the monitoring team. However, false positives remain, all of which trigger the alert within the vehicle even though no subsequent follow-up occurs.

The alert can be jarring and unpleasant for drivers. Of course, in genuine fatigue events this produces the intended result: it shocks the driver into a state of wakefulness. The TRGL compliance manager has viewed footage of a driver awakened by the system mere seconds before the vehicle was about to drive off a cliff. It is his subjective assessment, therefore, that the system saves lives. However, when the system is engaged because of false positives it can promote anxiety in drivers; a state best described as being 'on edge'. On occasion, drivers have been reduced to tears by the stress and discomfort caused by the alerts. The emotional and psychological impact of the alerts is under-researched and, at this point, poorly understood.

As noted, TRGL instituted a 'three strikes' rule for fatigue events. However, on occasion the risk posed by the first fatigue event is so high that the driver may be directed to stand down or take immediate rest. Such a decision has commercial repercussions: leaving a vehicle idle for one hour costs Toll and the site up to $27,000 and can compromise production targets. TRGL recognised that the commercial imperative might prompt managers to err on the side of cost rather than caution. Consequently, decision making authority on the risk posed by first and second fatigue events was vested in the compliance manager, rather than the site managers. This helped to mitigate the risk of prioritising production over safety considerations.

One of the challenges from an analytical perspective is that the system is configured to the truck rather than the driver. This means that fatigue reports are captured by vehicle and by shift. An additional administrative step is required to match that data to a driver as there may be more than one driver per shift. At this stage, TRGL has not had the resources to analyse the data at the driver level. The data that has been aggregated at the vehicle level suggests that drivers are at most risk of fatigue events between midnight and 6am with a pronounced peak at 4am, as illustrated in figure 4 below.

Lessons learned

TRGL's experience in using technology as a risk management tool for fatigue illustrates that technology is an enabler, not a panacea. In and of itself technology does not solve the fatigue problem. After all, the technology does not and cannot directly challenge the ideas about work, productivity and well-being that the driver cohort may hold. These ideas might include that it is 'unmanly' to admit to not being fit for duty or to acknowledge that there are personal or health problems that may be compromising restorative rest. Drivers sometimes identify with others who share their route or shift and may fear that they are 'letting the side down' if a vehicle is unproductive on their watch.

Such ideas can only be combatted through training, conversation, information, modelling the appropriate behaviours and trust. Cultural change is often slow and difficult, and it is important to bear in mind that until the 1980's safety was considered 'a peripheral concern' in the trucking industry (NTC, 2013, p.20). Technology supports cultural change by keeping health and safety issues such as fatigue management highly visible. It provides management with the data to report and track safety-related key performance indicators. As noted by Smith and Jones, the video footage is also a powerful training tool, providing drivers with objective evidence of problematic behaviours and a catalyst for change (Smith, Jones, 2015).

Introducing technology and leveraging from it effectively also requires a wholesale rethink about the skills and attributes needed in the heavy vehicle freight industry. Traditionally, the core competencies of a good trucking company were putting the right loads with appropriate restraints on the right vehicles and the right roads. Now, however, TRGL requires expertise in data monitoring and analysis, in coaching and mentoring drivers, in the promotion of health and wellbeing and even in psychological counselling. Technology will only deliver benefits where there is recognition of, and resourcing for, the new skills needed to profit from it. Trucking can no longer be construed as a 'blue collar' industry.

TRGL's experience also suggests the importance of forging a genuine, long-term partnership with an IT provider. Seeing Machines has shown a willingness to engage with and understand the specific needs and requirements of trucking in a mine-site environment. They have customised the system to reflect the operational reality. As the technology has improved and progressively eliminated false positives and design issues, TRGL has become an advocate for the technology. The relationship between technology provider and end user is therefore mutually beneficial.

Ultimately, the technology requires a human being to make a judgement call about whether a driver may safely continue to work. The system provides managers with better information than they would otherwise have, but leadership and accountability have to be in play for the system to work. All the data in the world means nothing without the authority and empowerment to say 'you are not fit to drive' as a result of it.

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Road safety: a reliable investment for every profitable heavy vehicle business

by Jerome Carslake
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Introduction

The majority of Australians take the road transport system for granted; few appreciating what lies behind moving people and goods seamlessly from A to B. The nation's productivity relies on a safe and efficient transport system.

It is the economy's life blood as well as the glue of our social fabric. However, the downside is serious injury and death which we must seek to eliminate. The only time transport comes into focus for the community is when something negative occurs and the lives of "Joe Public" are touched.

As the manager of the National Road Safety Partnership Program (NRSPP) I am privileged to interact with leading organisations where road safety is a core pillar in their daily operations. Almost all organisations – public and private – depend to some degree on safe and efficient road transport, thus Partners in the program come from all sectors, sizes and modes.

One sector strongly engaged in the NRSPP is the freight vehicle sector. These Partners are very active, keen to share their knowledge and raise awareness of just how hard they are working to improve road safety; and investing in their drivers and fleets to protect other road users.