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THE NEED FOR ENHANCED HEAVY VEHICLE CRASH INVESTIGATIONS: BEYOND 'BLAME THE DRIVER'

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Review article

Abstract: The heavy vehicle transport industry is considered to be the most dangerous to work in. The number of crashes resulting in injuries and deaths surpasses that of other transport and industrial sectors combined. The economic and personal impacts are immeasurable. There is a distinct absence of a uniform approach to investigating these crashes to identify the systemic causal factors, as is in place for other transport industries. There is a need for governments to accept that current investigation processes are not working and a new approach to investigating heavy vehicle crashes is needed to assure the underlying causes are identified, the lessons learned and effective corrective actions informed to prevent future crashes.

Keywords: Investigations, Transport, Heavy Vehicle, Fatalities, Crashes.

Introduction

In the aftermath of major incidents throughout the world such as the Pipa Alpha disaster that occurred on 6 July 1988 (Cullen, 1990) and the sinking of the Costa Concordia on 13 January 2012 (Ministries of Infrastructure and Transport, 2013) there has been a strong and recurring societal demand for public and independent investigations to be conducted (Roed-Larsen et al., 2004; Dechy et al., 2012; Strauch, 2017). This need set the framework for an international approach to implement transparent and accountable investigations with the aim to improve public safety within the transport sectors. For example, investigative agencies and boards dedicated to the transportation sectors (rail, aviation and maritime) were created to meet community needs (Stoop, 2004; Dechy et al., 2012). Notably however, no such investigative agency was established to support the road transport sector, specifically the heavy vehicle transport industry where the public interface is arguably greater.

Fatal and serious injuries resulting from heavy vehicle crashes represent a significant social, workplace and economic burden throughout the world. For example, within the European Union and the United Kingdom heavy vehicle crashes represent a significant portion of those killed and injured on roads (European Commission, Directorate General for Transport, 2016). In the United States of America, heavy vehicle crashes resulted in more fatalities than any other occupation (National Traffic Safety Administration National Centre for Statistics and Analysis, 2017). In Australia, the heavy vehicle transport industry has been identified as the most dangerous industry to work within, with the highest death rate of its workers compared to that of other industries (National Transport Commission et al., 2008; Walker, 2012; Transport Workers Union, 2015).

The study of crashes is recognised as a way of acquiring knowledge that can improve the socio-technical system of the heavy vehicle transport industry and in so doing inform effective crash prevention strategies (Cassano-Piche et al., 2009). The appropriate application of an investigative methodology that looks beyond the factors related to drivers and driver behaviour is likely to lead to a reduction in crashes.

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In some jurisdictions other regulatory arrangements require investigative agencies to focus primarily on driver behaviours (Salmon et al., 2012). There has been broader research into safety in the heavy vehicle industry (e.g. Duke et al., 2010; Salmon et al., 2012; Elkington and Stevenson, 2013; Warmerdam et al., 2017), exploring such issues as driver fitness, age, fatigue and speeding, as well as factors which relate to failures in the application of legislation intended to evoke responsibilities on all parties in the supply chain. However, the literature appears to be silent in establishing if the laws have been effective in reducing the number of crashes and fatalities. Moreover, the literature does not examine the quality of information being captured from fatal crash investigations that can be useful in revealing the underlying causes (Brodie et al., 2009; Brodie et al., 2010). It was established that in complex systems the analysis of an event is contained in a number of factors, these being the quality of data captured, the training, skills and competencies of the investigator and the maturity of the associated reporting system (Grabowski et al., 2009; Roed-Larsen and Stoop, 2012; Dechy et al., 2012).

The literature and data suggest that the same or similar crashes continue to occur. This would indicate a failure to learn from previous events (Cook and Woods, 2006; Toft et al., 2012; Stemn et al., 2018) or that previous events have not been investigated adequately to identify the system causation factors, as called for by Brodie et al. (2009 and 2010), that could be used to mitigate a recurrence.

Research to date suggests there is a lack of standardised crash investigation and reporting processes leading to misunderstanding the impacts of those causal factors that contribute to a crash (Duke et al., 2010; Edwards et al., 2014). Supporting research concluded that limited investigative resources and a lack of standard investigation approaches may impede the information and investigative process (Driscoll, 2003; Brodie et al., 2009; Brodie et al., 2010). Similarly, Bohensky et al. (2005) found that fatalities that repeatedly occur, are more easily and efficiently investigated if the process for investigating these deaths is standardised.

The public perception is that the risk of incidents, disasters and catastrophes is growing (de Bastos, 2004; Roed-Larsen and Stoop, 2012) and in the heavy vehicle transport industry latent causes are not often gathered as they are in the rail, aviation and maritime industries (de Bastos, 2004).

Methods

This literature review focussed on identifying major themes and recommendations that discussed investigative methodologies into heavy vehicle crashes and fatalities.

A systematic literature search was conducted utilising key online research engines. Search terms were entered into the following databases: EBSCO host, ProQuest, Informit, Scopus, PschyInfo, OVID Medline, Embase, Web of Science TRID and Google Scholar. Literature searches were also conducted in relevant road safety and regulator websites associated with heavy vehicle safety and fatality investigations, internationally, including Europe, the United Kingdom, the United States of America, Australia and New Zealand.

Search terms included: safety, fatalities, systems failures, heavy vehicle, coronial investigation, transport, investigation methods, heavy vehicle safety, heavy vehicle transport system, road transport safety, heavy vehicle fatalities, heavy vehicle crashes, heavy vehicle investigations and heavy vehicle coronial investigations. Each article/report was assessed for eligibility against three criteria, namely: (1) publication date must fall between the years 2000 and 2019, and must include (2) reference to the heavy vehicle transport industry, and (3) international research into systems analysis and investigations. Thematic analysis was conducted to identify major themes regarding the current state of knowledge on investigations of heavy vehicle transport crashes in the literature. The initial search captured 78 potential articles. After reviewing the abstracts, 31 articles met the three criteria set and were deemed acceptable for this review.

Magnitude of the Problem - Road Crash Statistics

The scale and significance of the problem is felt worldwide. For example, between 2009 to 2014 there were in excess of 26141 heavy vehicle fatalities recorded within the European Union member states (European Commission, Directorate General for Transport, 2016; European Transport Safety Council, 2020). In 2013, the European Road Safety Observatory (2017) reported that in the United Kingdom more than 52 percent of fatal crashes that occurred on the motorways involved heavy vehicles, with over 5200 people being killed in those crashes. In the United States of America, the Federal Motor Carrier Safety Administration (2019), reported in 2015 that there were 4889 large truck and bus crashes involved in fatal crashes.

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In New Zealand, there were 680 heavy vehicle crashes in 2016, of which 60 involved at least one fatality (Ministry of Transport New Zealand, 2016). The Australian statistics reflect a similar rate. As an exemplar in the three years between March 2015 and March 2018 there were 605 deaths from 444 fatal crashes (Bureau of Infrastructure Transport and Regional Economics, 2016; 2017 and 2018).

Available data shows the total social and economic cost of road crashes globally exceeds more than one trillion dollars ($US) a year. In the 28 member states of the EC the cost was estimated to be ($US) 303 billion (Wijnen et al., 2017) which included the United Kingdom where the figure was in excess of ($US) 22 billion. In a study released by the National Highway Traffic Safety Administration National Centre for Statistics and Analysis (2015) the total cost of road fatalities to the United States of America economy was ($US) 871 billion. In Australia the total social cost of road crashes in 2016 was estimated at being ($US) 21.6 billion and this is likely to be a low estimate (Litchfield, 2017) with heavy vehicle crashes representing a significant portion of these fatalities (Bureau of Infrastructure, Transport and Regional Economics, 2018). The personal and emotional impacts of a fatality on a family are incalculable.

These statistics clearly show that crashes, including heavy vehicle crashes, are a critically important social, personal and economic problem for industry. The cost is immeasurable to families of those affected as well as the community and warrant further research into the causes of heavy vehicle crashes and the effectiveness of the relevant legislation and aspects of the heavy vehicle safety management system such as crash investigation processes.

The need for Specialist Road Crash Investigation Agencies

Investigation methods for heavy vehicle crashes around the world vary widely with no common structure or standardisation. Most are reliant on methodologies which are not systems-based (Newnam and Goode, 2015). However, within other industries new processes continue to emerge with a primary focus on understanding why incidents occur and how to use the findings to provide the correct information about underlying causes to decision-makers (Lundeberg et al., 2012). Unfortunately, this process is not the primary consideration for road crash investigations, particularly heavy vehicle crashes, where critical information is either missed or omitted by investigators who do not apply a 'systems-based' approach to understanding or identifying why these crashes occur (Salmon et al., 2012; Newnam and Goode, 2015).

Separate investigations are set up by various governments and agencies to investigate rail, aviation and maritime incidents of significance (de Bastos, 2004; Elliman et al., 2007; Roed-Larsen and Stoop, 2012). The investigations conducted by these agencies have a focus on identifying causes and potential preventative measures, an approach which is clearly distinct from that of Police investigations into heavy vehicle crashes which typically focus on determining fault and assigning blame as a consequence of deficient performance against road safety laws (European Commission, 2006; Salmon et al., 2012; Newnam et al., 2017). It has been found that crash investigations are faced with a number of competing priorities that present challenges and this includes a lack of integration of investigation process arrangements at various institutional and political levels (Lundberg et al., 2010). There are a number of competing priorities, differing interest and focus held by the varying stakeholders, organisations and government agencies that arguably adversely affect the investigative outcome (Roed-Larsen and Stoop, 2012). Many countries have constituted separate single sectorial investigative bodies in one or more of the three primary transport fields, rail, aviation and maritime industries, based mainly on international regulations (Roed-Larsen and Stoop, 2012). The data, as well as immediate root causes, are often gathered through the various types of investigations, commissions and boards that have been set up, however the road transport industry has largely been excluded.

In 2004 the European Union appointed a special expert group to advise the Commission on investigating transport sector crashes. The group successfully proposed several recommendations on a revised methodology for the investigation of crashes in the transport sector (de Bastos, 2004; European Commission, 2006). The European Commission made investigative bodies into the rail, aviation and maritime sector a mandatory requirement by European Commission Council directive 94/56 article 6. A number of recommendations, primarily focused on setting up an independent Public Safety Investigation Agency have been made which included the introduction of a holistic cross sectorial investigative body (de Bastsos, 2004; Dechey et al., 2012; Roed-Larsen and Stoop, 2012). The research concluded that crash investigations have a long tradition in three primary transport sectors of rail, aviation and maritime, whereas road crashes, including heavy vehicles, have been

treated as single events investigated mainly by the Police (European Transport Safety Council, 2001; de Bastos, 2004; Stoop, 2004; Roed-Larsen and Stoop, 2012).

Operating in line with the EC mandate the United Kingdom has a Department of Transport that includes three separate crash investigation branches to investigate rail, aviation and maritime incidents (Elliman, 2007). In 2005 the United Kingdom set up the Railway Accident Investigation Board following the rail catastrophe that occurred at Ladbroke Grove on 5 October 1999 (Cullen, 2001, part 1 and 2). In 1967 the United States of America established the National Transport Safety Bureau that has specialist agencies to investigate these three modes (Dechy et al., 2012). Australia has a specialist agency, the Australian Transport Safety Bureau, to investigate incidents in all three modalities, aviation, rail and maritime that focuses on a no blame, no liability approach to their investigations. Australia also has the Office of the National Rail Safety Regulator, the Civil Aviation Safety Authority and the Australian Maritime Safety Authority who carry out regulatory investigations. Additionally, Australia has workplace safety regulators established in every state and territory who conduct investigations into workplace and industrial incidents. There is however no specific independent national entity or agency in Australia to investigate fatalities in the heavy vehicle transport industry apart from the Police.

In some instances, such as a major international airline crash, a rail derailment involving multiple fatalities, a sinking ship or an oil refinery explosion, countries may establish a special commission of inquiry to investigate these types of major incidents. This will be dependent on the scale of the incident, its impacts on industry, society, environment, politics and the level of public scrutiny. For example, the Grayrigg train derailment that occurred in the United Kingdom on 23 February 2007 (Rail Accident Investigation Branch, 2011) or the Germanwings Flight 9525 crash that occurred in France on 24 March 2015 (French Civil Aviation Safety Investigation Authority, 2016).

There are however some European countries that have identified the critical need to investigate road sector crashes and have implemented additional specialist agencies to do so. For example, Finland has a permanent investigation board specific to the road sector. Several other Nordic countries have multi-modal boards that cover road crashes such as the Norwegian Accident Investigation Board and the Dutch Safety Board (de Bastos, 2004; Dechy et al., 2012). In Sweden, there is the Swedish Board of Accident Investigations (SHK) which investigates not only rail, aviation and maritime incidents but also road traffic and other accident and military occurrences. It must be noted that the SHK only investigate commercial or public transportation events where several persons have been killed or injured, substantial damage has been caused to property or a high probability of such serious outcomes (Swedish Accident Investigation Authority, 2020). A key requirement for investigation is that there are important safety lessons to be learned. Sweden also has the Swedish Centre for Lessons Learned from Incidents and Accidents, the principle being to communicate knowledge of all learnings from accidents to all stakeholders for the purpose of preventing occurrence of similar events, limiting damage and thereby improving safety (Lindeberg et al., 2010; Dechy et al., 2012). Within some other European countries, the recommendation for an independent transport agency specific to investigate road transport crashes is already gaining some traction. Importantly, proposals for the implementation of systemic, scientifically based investigative methods are also being made, and include such measures as ensuring investigators are trained, skilled, qualified and competent (Elliman, 2007; Roed-Larsen and Stoop, 2012; Dechy et al., 2012).

Compared with other transport modes, the heavy vehicle transport industry is disadvantaged and largely ignored. There are shortcomings in both the investigative methodological requirements and ill-defined investigative processes (Brodie et al., 2009; Brodie et al., 2010). Current methods can be best described as being asymptomatic with high priority being towards focusing blame or guilt on the driver (Newnam and Goode, 2015; Newnam et al., 2017). The problem continues and solutions are needed to reduce the incidence of the number of crashes, injuries and fatalities (Roed-Larsen and Stoop, 2012).

What is being done about Heavy Vehicle Crash Investigations?

There is a clear need for effective road crash investigation which can lead to development of strategies and preventative measures. According to a report by Elliman et al. (2007), there is no requirement for member states of the European Union to set up independent organisations responsible for road crash investigations unlike what has been set up for rail, aviation and maritime. At the time the researchers found this extremely surprising given the significant disparity in the number of those killed between the transport modalities. In 2004 the number

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of road fatalities in the European Union was 42472, dwarfing rail fatalities 105 and aviation fatalities 6 (Elliman et al., 2007). This is clearly reflected in reports which indicate that in the European Union, road accidents cause the most human consequences of any transport sector (Dechy et al., 2012).

To improve road safety, recommendations for investigative best practice of road crashes were made by Elliman et al. (2007) for each member state to have an organisation that is responsible for such investigations. There are however no binding international rules of investigation into traffic and other serious crashes let alone for heavy vehicles as there is for rail, aviation and maritime (Elliman et al., 2007).

In the United Kingdom in 2015, the need to investigate road crashes using similar 'systems-based' investigative methodologies and processes was recognised by the Transport Safety Commission. It called for improvements to investigating road crashes where lessons learned could be separated from prosecutions (Transport Safety Commission United Kingdom, 2015). In support of the Transport Safety Commission findings, Gooding (2017) did not believe there was sufficient attention paid to root cause analysis or to exploring the changing pattern of road crashes and their causes over time. Gooding (2017) concluded that a lack of a genuine systems approach was evident. Jackson and Kyle (2018) similarly identified that the approach to crash investigation on roads has traditionally been focused on the driver and the vehicle, and as such differs from the system focused approach used in rail, aviation and maritime investigations. Gooding (2017) called for an independent road crash investigation agency to be introduced in the United Kingdom and was supported in a paper completed by Jackson and Kyle (2018). An independent Australian investigation agency to specifically investigate heavy vehicle crashes has also been called for (Kozoil, 2018).

In earlier Australian studies by Brodie et al. (2009) and Brodie et al. (2010), it was concluded that the lack of using a systematic investigative method into heavy vehicle crash investigations likely resulted in an absence of information in Coroner's files. Their research established that regulators viewed heavy vehicle fatal crashes as being largely a road safety issue which failed to take into consideration the need to identify contributory factors that go beyond the driver. The authors' found there was the justification and need to adopt consistent investigative methods that included the systemic examination of contributing factors rather than simply focusing on drivers' behaviours (Brodie et al., 2010). Furthermore, their research concluded that information collected from heavy vehicle fatal crash investigations by regulatory agencies such as the Police, were not detailed enough or conducted to a sufficient standard for Coroners to make findings. In many instances the Coronial outcomes resulted in no recommendations being made at all, mainly due to the lack of information being captured by investigators (Brodie et al., 2009; Brodie et al., 2010). It was concluded that recommendations arising from a heavy vehicle fatal crash investigation should ideally systematically examine contributing factors rather than looking at a single cause (Brodie et al., 2010; Salmon et al., 2012; Newnam and Goode, 2015; Newnam et al., 2017).

Several scholars have recommended that standardised improvements are required in how crash investigators identify and categorise crash data to compliment the investigative processes (Davey et al., 2008; Brodie et al., 2009; Newnam and Watson, 2010; Burke et al., 2016). These findings were supported in additional research by Sochon et al. (2013) that concluded inconsistent enforcement, investigative practices and isolated non-descript methods, in collecting crash related data amongst enforcement agencies, were undermining the effective safety outcomes of crash investigations. Rasmussen (1997), Perrow (1999), Leveson (2004), Dekker (2011), Toft et al. (2012), Hollnagel (2012) and Sochon et al. (2013) all suggested that systemic understanding of causation is intrinsic to successful prevention. So, if crash investigations are effective, then there should be a decrease in the number of crashes as the underlying causes to these crashes are being identified and mitigation actions implemented (Toft et al., 2012; Sochon et al., 2013).

Studies into the causation factors of heavy vehicle fatal crashes concluded there is the need to develop a domain specific investigative methodology to identify the underlying causes contributing to a heavy vehicle crash (Salmon et al., 2010; Salmon et al., 2012; Newnam and Goode, 2015; Newnam et al., 2017). The studies identified a pressing need to develop an industry wide reporting and analysis system so that the causation factors of a heavy vehicle crash can be identified, and the blame culture focus of a driver centric approach be removed.

It is evident from the research there is consensus that systems investigations, if completed as intended, remove the focus from the individual to look at other underlying causes such as organisational interactions and factors. Bird et al. (2003) identified that early incident investigations within the oil and gas industry focused too much on assigning blame and rarely delved into systemic reasons. The outcome of these ineffective investigations was that incidents

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continued to occur unabated as the many underlying causes were not being identified. It is evident that this is a problem that still exists within the heavy vehicle transport industry.

Heavy vehicle fatalities are not given the due attention they deserve especially when only a single driver is involved and blame cannot be attributed, or where the simplest course of action is to blame the driver (Newnam and Goode, 2015). The rail level crossing crash at Kerang in Australia, on 5 June 2007 is a key case in point. The driver of a large articulated heavy vehicle was charged with a number of criminal offences for failing to stop at the level crossing and colliding with a passenger train. The crash resulted in the deaths of 11 passengers and injuries to 23 others who were all on the train. The level crossing was protected by active prevention systems. There were warning lights and audible warning bells to indicate the approach of a train, however the level crossing was not controlled by boom gates. Crash protection in that environment relied on road vehicle drivers seeing the level crossing warning of the approaching train and stopping short of the rail line. Little is known about the causal mechanisms involved in this crash despite a high-profile investigation and court proceedings. Exactly why the driver of the heavy vehicle failed to heed the warning devices at that level crossing remains unexplained (Salmon et al., 2013). As evidenced by the investigation by the Office of the Chief Investigator (2007) instances of driver non-compliance are extremely difficult to explain even when there has been a significant investigation (Salmon et al., 2013). Despite this the Police investigation attributed blame and charged the truck driver with culpable driving. However, the court found in favour of the truck driver who was acquitted.

Salmon et al. (2013) acknowledged the driver of the truck made 'errors', however other factors from the road and rail system played a part, stating *"The extent to which drivers can be blamed in the context of wider system failures should be questioned"*. In a review of the Salmon et al. (2013) analysis of the Kerang rail level crossing crash, Scott-Parker et al. (2015) found the Police investigation did not take into consideration a number of factors including *"road design, trees in close proximity to the crossing, delayed loading of the truck, limited rail level crossing risk assessment process, rail level crossing design, financial constraints"*. In the analysis of the Kerang crash, Salmon et al. (2013) concluded:

"A shift away from individual blame and culpability to a learning culture for system improvement is needed. This can only occur when the complexities of human behaviour and the impact of the system on behaviour is understood within the road and rail industries, government, the legal system and society at large".

Other authors also agree that the level of investigative focus on crashes is limited and dependent on the investigator's knowledge, competence and experience (Brodie et al., 2009; Brodie et al., 2010; Roed-Larsen and Stoop, 2012), and their theoretical approach they apply and the accident models they use. As Dekker (2006) suggested, the accident investigation approach used will determine what is found:

"A model helps you determine what things to look for. It brings some kind of order into the rubble of failure because it suggests ways in which you can explain relationships. So the accident model that you believe in - probably without knowing it - is enormously helpful. But that model is also constraining. After all, if the model tells you to look for certain things, and look at those things in a particular way, you may do just that - at the exclusion of other things, or at the exclusion of interpreting things differently".

Accordingly, so long as a 'blame the driver' model is applied to heavy vehicle crash investigations, understanding of systemic causes essential for effective prevention will continue to be overlooked (Salmon et al., 2013). This was also supported in a Coronial Investigation of 26 rail crossing fatalities in Victoria, Australia, between 2002 and 2009. The first recommendation made by the Coroner was the need for regulatory agencies to adopt a systematic approach to collecting detailed human factors information about level crossing collisions (Coroners Court of Victoria, 2013). Summarily Lundeberg et al. (2010) suggested:

"The limited scope of investigation of causes to those that are preventable can be a source of bias in examining a bigger picture of causes of accidents at large - which becomes limited to those causes that are currently seen as fixable by investigators".

In support, Dell (2015) stated:

"There has also been a continuous effort to address the problem with emphasis on apportioning the blame for accidents to individuals and then taking legal action against them. Too often, those directly involved in accidents, such as the driver of the vehicle, the pilot of the aircraft or the operator of the machine, are the ones that are blamed".

Investigations of heavy vehicle crashes that have limited scope of focusing on driver behaviour and breaches of the law would be affected by similar bias *"that lead investigators away from the ideal"* (Lundeberg et al., 2010).

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Discussion

Crash investigations have come under public and political scrutiny due to the changes in socio-technical systems and operating environments. Roed-Larsen and Stoop (2012) go onto suggest that in order to cope with developments in quality assurance and improving public credibility modern investigations face a series of challenges with a need to shift the focus towards improved performance. This incorporates developing investigator training competencies, broadening investigations to included other factors influencing causation such as resourcing, independence, training and management oversight scientific interest in their methods, models and practices (Cedergren and Petersen, 2011). Depending on the type of incident, its effects on the economy, the community, its political impacts, the public scrutiny and based on number of fatalities, separate investigations may be set up for a singular event such as those implemented for events that occur in the rail, aviation or maritime modes (McInerney, 2005; Roed-Larsen and Stoop, 2012). To address the need the European Commission has created specific investigative agencies for rail, air and sea, when crashes arise. This is now mandatory, as well as appointing a special expert group to advise on a strategy for dealing with these transport crashes (European Commission, 2003), however a similar agency specific to the investigation of heavy vehicle transport crashes has not materialised.

In order to prevent crashes, it is essential to learn from previous crashes (Lindberg et al., 2010). This was clearly highlighted in research undertaken into the roles of incident investigations conducted at a Scandinavian refinery (Vastveit and Nja, 2014). This research identified how investigations played an important part in the ongoing learning process both during the investigation, so that mitigations can be implemented promptly even as investigations progress, depending on urgency, and upon completion of the investigation. These researchers also found that investigations generated new knowledge about the cause of incidents, confirmed existing knowledge and was an important factor in contributing to learnings (Lindberg et al., 2010; Dechy et al., 2012; Vastveit and Nja, 2014).

The failure to learn, resulting in loss of life in the same incident type, is not new and continues to occur because industry does not utilise the knowledge from the past (Dodshon and Hassall, 2017). Accordingly, the primary purpose of an investigation is to systematically analyse the reasons why a crash occurred, identify all causal factors and make effective recommendations to prevent reoccurrence (Lindberg et al., 2010; Dechy et al., 2012; Vastveit and Nja, 2014; Wachter and Yorio, 2014; Manuele, 2014).

It is important to take into consideration the heavy vehicle transport industry is complex and the causal factors of crashes can emerge from anywhere in the entire socio-technical system (Salmon et al., 2012; Salmon et al., 2016). Understanding is required in how the socio-technical system components interact in the lead up to a crash. However, current investigative methods are not specifically designed to analyse the dynamic complexity of heavy vehicle crashes (Newnam and Goode, 2015; Salmon et al., 2016; Newnam et al., 2017).

As previously discussed, the investigation model used can determine what is found and essentially directs the path the investigation takes (Dekker, 2006; Hollnagel, 2008; Lundberg et al., 2009; Dekker, 2011). The consensus of authors suggests that without an investigative model there is no guidance. However, the authors warned that whatever model is used needs to be carefully considered to ensure that it is appropriate for the industrial context, social-technical setting, the nature of the crash and the scope of the investigation being undertaken. Society's understanding has not kept up with the complexity of modern-day systems (Dekker, 2011) and current investigative processes simply cannot address the complexity in the heavy vehicle transport system due to its many emergent parts. Therefore, it is vital to consider a suitable and consistent investigative model for heavy vehicle transport industry that has both the ability and flexibility to cope with such system variations otherwise there is the risk that what you look for is what you find (Dekker, 2006; Hollnagel, 2008; Lundberg et al., 2009; Dekker, 2011).

Crash analysis methods, models and tools which identify underlying causes, should be reliable, valid and suitable for the investigation (Waterson et al., 2017) and many researchers discussed here suggest that this is particularly relevant to crashes in the heavy vehicle transport industry. Indeed, it would be pointless to employ a method that does not pass the basics of reliability and validity and will not achieve outcomes that identify essential learnings (Barber and Stanton, 2002). Accordingly, the heavy vehicle transport industry requires a consistent systemic approach to investigating heavy vehicle fatalities, as has already successfully been applied in the rail, aviation and maritime industries.

Recent investigations undertaken in the rail, aviation and maritime sectors have seen the increasingly clear distinction between the search

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for causal factors and identifying preventative measures and the long-time practice in the heavy vehicle transport industry where investigations primarily determine blame (European Commission, 2006).

The advocacy for independent investigations to identify systemic causes rather than apportioning blame, will still face opposition as a consequence of the legal questions surrounding the possible culpability of individuals (Van Vollenhaven, 2006). This idea was reinforced by several authors that suggested the enforcement objective of some crash investigations, for example crash investigations conducted by Police to establish liability, has a number of failings, including the failure to identify preventative measures (Brodie et al., 2009; Brodie et al., 2010; Newnam and Goode, 2015; Salmon et al., 2016). These authors have voiced concern that the fidelity of those investigations adversely affect outcomes. Furthermore, the investigations that focus on individuals instead of systems, concentrate on legal aspects instead of the identification of multiple causes, and identifying and promoting preventative measures (Roed-Larsen and Stoop, 2012).

Researchers recognise that few studies have been conducted that investigate underlying causes of fatality crashes in the heavy vehicle industry (Bugeja et al., 2007; Brodie et al., 2009; Brodie et al., 2010; Duke et al., 2010; Newnam and Goode, 2015; Newnam et al., 2017). Not surprisingly, it is evident there are significant weaknesses in heavy vehicle crash reporting and investigation methods. This weakness requires immediate action to develop a methodology that will be both applicable and suitable (Salmon et al., 2012). Without a systematic approach to investigation of heavy vehicle crashes, the investigations in the industry will likely remain substandard and underlying causal factors will be overlooked. Salmon et al. (2012) concluded there are clear benefits to applying systematic crash analysis in an investigation as this will lead to the contributing factors within the heavy vehicle transport system being identified.

Whilst researchers acknowledge that heavy vehicle crashes are a result of various contributing factors, regulatory agencies continue to attribute blame on the driver (Salmon et al., 2012; Newnam and Goode, 2015; Newnam et al., 2017). This omission has for some time been recognised as problematic by safety experts who have stated that a focus on blaming drivers does not contribute to useful crash investigations or to improved safety outcomes (Rasmussen, 1990). Scholars acknowledge that driver behaviour at the time of a crash can be challenging, especially when determining what caused the crash (Quinlan, 2001; Jones et al., 2003; Walker, 2012; Thompson and Stevenson, 2014; Thompson et al., 2015). The evidence from these authors suggest there are underlying causes that contribute to drivers' behaviours that result in crashes. These include factors such as scheduling, number of hours worked, start and finish times, and financial pressures which can lead drivers to make decisions that cause them to breach road rules causing, or in some cases, forcing them to speed or drive for lengthy periods resulting in fatigue. However, the underlying causes for why drivers are speeding or why drivers are fatigued is largely ignored or omitted from the investigation (Quinlan, 2001; Jones et al., 2003; Mayhew and Quinlan, 2006; Wright and Quinlan, 2008; Thompson and Stevenson, 2014; Thompson et al., 2015; Burke et al., 2016; Williamson and Friswell, 2016).

It is clear that investigations attributing cause to driver error or conclude with assertions of blame or culpability fall short of the requisite standard to prevent recurrence. Indeed, a finding of driver error ought to be the beginning of an investigation line of inquiry to gain understanding of the underlying factors that led to the error (Leveson, 2019; Dell, 2019). Therefore, it is important that investigations examine in detail those aspects of the heavy vehicle transport socio-technical system which influenced the behaviours of the drivers. An investigation methodology is needed that captures the interactions between all components of the heavy vehicle transport system to create the conditions that influence and impact upon driver behaviour (Salmon et al., 2012).

Many researchers have also called for additional research into the underlying causes of heavy vehicle crashes (Brodie et al., 2009; Brodie et al., 2010; Duke et al., 2010; Salmon et al., 2012; Mooren et al., 2014; Warmerdam et al., 2016).

Conclusions

It is evident that driving heavy vehicles is a dangerous and deadly occupation. The failure to use a uniform systematic investigative process ensures the causal factors from the various parts of the heavy vehicle transport system are not captured. The blame continues to be focused on the driver and does not help identify where the system failed nor does it help improve heavy vehicle safety. This failing takes the focus away from identifying the underlying causes that lead to crashes.

Heavy vehicle transport is a significant transport mode that requires similar frameworks to the rail, aviation and maritime domains to investigate

the causal factors of crashes across the entire socio-technical system, to inform effective corrective actions that extend beyond the factors associated with the driver and driver behaviours to reduce the risk of future crashes. This is needed to identify the influencing factors that have contributed to crashes so that government policy makers and industry stakeholders can be informed and targeted interventions implemented across the socio-technical system of the heavy vehicle transport industry.

Finally, without establishing a specific independent investigation agency, as has been introduced to cover the rail, aviation and maritime industries, it is also likely blame will continue to be focused on the heavy vehicle driver and the lessons and the opportunities for the reduction in the number of crashes will be lost. The research shows that an independent investigative agency, specific to heavy vehicle transport industry, is needed.

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