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SYSTEMIC FAILURES AND UNDERLYING CAUSES-AN ANALYSIS OF THE HEAVY VEHICLE SOCIO-TECHNICAL SYSTEM

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Review article

Abstract: The heavy vehicle transport industry has been described as one of the most dangerous occupations with a high death rate. It is part of a complex socio-technical system with many interacting parts which can adversely influence a drivers decision leading up to a crash. Drivers continued to be blamed for crashes without the underlying causes being identified as investigation methods do not take these causes into consideration. This paper explains the complexity of the socio-technical system and suggests it is necessary to look beyond a driver's behavior and focus on the actions and inactions of other actors that have influenced the driver's behavior to understand what has caused a crash.

Keywords: Socio-technical System, Drivers, Heavy Vehicle, Blame, Crashes, Underlying Causes.

Introduction

The heavy vehicle transport industry in Australia is a vital lifeline, being an essential mode of delivering freight and goods to all areas in Australia, particularly remote areas inaccessible to any other modes of transport. The transport activity contributes $122.3 billion (AUD) to the economy making it the fourth largest industry in Australia (RRATRC, 2021). The Rural and Regional Affairs and Transport References Committee (RRATRC, 2021) has described the industry as one of the most dangerous industries in Australia and that there is a crisis within the industry caused by pressures that influence heavy vehicle driver behaviour. These pressures, such as economic and contracting pressures are caused by the behaviours of other actors in the socio-technical system within which the heavy vehicle transport industry operates These actors include the clients, other contractors, company owners, Government, enforcement and regulatory agencies and management to name a few (Quinlan, 2001; Jones, 2013; Mooren et al., 2015; Cikara et al., 2020a).

The RRATRC (2021) referenced statistics revealing the social and economic cost associated with death and injuries in the heavy vehicle transport industry. In those statistics it was identified there are *„approximately 200 heavy vehicle crashes each year resulting in fatalities, 1500, crashes leading to hospitalisations, 11 000 crashes resulting in less serious injuries and 32 000 crashes causing property damage"*. The cost of these heavy vehicle crashes accounting for over $4.64 billion (AUD) in costs alone (RRATRC, 2021).

The heavy vehicle transport industry operates within a complex socio-technical system that comprises many elements, entities, networks, structures, interactions and interrelationships between the varying levels of the system (Anderson and Bailey, 2005; Farnsworth and McCarthy, 2016). Each element is distinct from each other with independent and separate controls that interlink through the integration between the elements. Socio-technical systems recognize the interactions between people, technology and the environment, any one of which, should there be failures, can impact the other (Wang and Wells, 2020).

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There are a combination of interactions between actors and elements within the socio-technical system that can affect performance and be influenced by a number of factors (Newnam and Goode, 2015). Deficiencies in part of the system can emerge or manifest itself into adverse outcomes in other parts of the system involving other actors with unintended consequences. The migration of influence an affect can occur at any or multiple elements of the system, not just one, where there is a degrading or erosion of controls that manage safe performance (Rassmussen, 1997; Newnam and Goode, 2015).

Socio-technical systems are linked to sub-systems and activities which are linked in both known and unknown ways, in what has been described as being a complex, non-linear and uncertain dynamic environment. This is largely due to the complexity and setting of the socio-technical system and the multifaceted levels of connections, exchanges and behaviors between the actors, technology, equipment and environment as well as those influencing elements that are beyond the control of any one actor (Grant et al., 2018; Hollnagel, 2012; Salehi et al., 2020). The behavior of the socio-technical system does not always depend on the activities of its components that consists of technologies, humans, organizations and the environment (Underwood and Waterson, 2014; Salehi et al., 2020).

Waterson et al. (2017) argued that a breakdown in the control of any part of the socio-technical system and its hazards could result in a potentially harmful process resulting in a critical incident. It was suggested that the beginning of a crash is shaped over time by the interactions and efforts of actors within and linked throughout the socio-technical system. This includes the various degrees of interactions and engagement between the organization, employee, employer, client, technology, environment, the regulator and government (Duzguin and Leveson, 2018). A simple variation or deviation from the accepted or required practices in an actor's behavior, or failure to adhere to the required behaviors as set out by law, can 'turn on the switch' on a path towards a critical incident (Waterson et al., 2017). This can be problematic when analyzing the causes of crashes as it requires an understanding of the socio-technical system and how it works.

Rasmussen and Svedung (2000) stated:

„The propagation of an accidental course of events is shaped by the activity of people that either can trigger an accidental flow of events or divert a normal flow. Safety, then, depends on the control of work processes so as to avoid accidental side effects causing harm to people, environment or investment.“

Read et al. (2021) argued that a systems thinking approach considers the overall system and studies how components within that system interact to produce a crash. Rasmussen and Batstone (1991) emphasized that the potential for major incident occurring is increased due to increasing commercial and competitive pressures together with societal and technological advancements on companies (Quinlan, 2001; Waterson et al., 2017). Economic and client pressures, and decisions from within organization, are but some factors that form part of the influences that generate settings for crashes to occur (Quinlan, 2001; Jones, 2013; Read et al., 2021). The dynamic safety model (Rasmussen, 1997) demonstrates how these economic and external pressures, influences and considerations can shift the system closer to a margin of error and away from safe performance (Rasmussen, 1997; Quinlan 2001; Mooren et al., 2015; Waterson et al., 2017).

In studies undertaken by Underwood and Waterson (2014), it was identified that the systems approach in crash analysis and human factors research is arguably the dominant exemplar. This views crashes that occur within the socio-technical system as being the consequence of unexpected uncontrolled interactions between integral parts within a system. That is, crashes occur as a consequence of an intricate series of events within the normal operational capability of a system (De Carvalho, 2011). Using an investigative method that is direct, describing crashes in a sequential fashion is arguably unsuitable as this method may not properly explain the non-linear intricacy of a heavy vehicle crash (Hollnagel, 2004; Lundberg et al., 2010). This can lead to the driver being blamed for the crash rather than taking into consideration other critical links within the socio-technical system. Moreover, underlying causes are not identified which creates missed opportunities for key learnings that could develop informed and relevant recommendations to improve safety for the heavy vehicle transport industry (Underwood and Waterson, 2014).

Studies conducted by Bugeja et al. (2007) recognized that investigations into heavy vehicle crashes needed to be improved in order to identify systematic failures. Numerous studies support this conclusion and have identified there is limited research reporting on outcomes from crashes (Bugeja et al., 2007; Brodie et al., 2009; Brodie et al., 2010). Previous studies by Duke et al. (2010), Mooren et al. (2014) and Warmerdam et al. (2017) also concluded that more detailed analysis of factors that contribute to a crash are needed. They recommended the need for improved analysis of crashes by capturing other factors that contributed to

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the crash and that more, by way of investigations, was warranted. Research by Newnam and Goode (2015) concluded that current investigations focus blame on the driver for the cause of a crash and fails to look at the contributing system failures. This was followed up in a subsequent study by Newnam et al. (2017) who completed a content analysis of Coroners findings from heavy vehicle fatal crashes and found that, at all levels of the socio-technical system, contributory factors were found. Additionally, Newnam et al. (2017) found that focusing blame on the driver will not help identify and develop appropriate policy needed for effective interventions to improve heavy vehicle driver safety.

Methodology

A literature search, using key online search engines, was conducted to undertake a search of the key terms. The databases used included: Embase, Informit, PschyInfo, ProQuest, EBSCO host, Scopus, OVID Medline, Web of Science TRID and Google Scholar. Additionally, relevant road safety and regulator websites associated with heavy vehicle safety were also used in this search. These websites included: the National Heavy Vehicle Regulator; National Transport Commission; National Truck Accident Research Centre; Police Service Websites (Australia wide); Road Safety Commission, Western Australia; Safe Work Australia; SafeWork NSW; Transport Accident Commission, Victoria; VicRoads Victoria; NSW Roads and Maritime Authority; and publicly available coronial inquest and non-inquest findings from all state coroner websites.

The following search terms were used: safety, systems failures, heavy vehicle, transport, system methods, heavy vehicle safety, heavy vehicle transport system, road transport systems, socio-technical system, national law and compliance and enforcement. Each article/report was reviewed to ensure it was suitable and had to include reference to the heavy vehicle transport industry, and international research into socio-technical systems and systems analysis.

The search did not reveal an extensive selection of academic literature that met the search criteria and captured 77 potential journals. Each journal was further reviewed for eligibility against two criteria, these being: (1) there must be a reference to socio-technical system within which the heavy vehicle transport industry operated (2) the date of publication of the journal must be between the years 1990 and 2020. As a result, 57 journals were considered to meet these criteria. The 57 journals were then further analyzed by using a combination of search terms. Journals which did not take into account a reference to two or more search terms were excluded. After reviewing the journals, the list was narrowed down to 18 articles/ reports that met the set criteria and determined to be acceptable for this review.

Discussion

Heavy vehicle socio-technical system

Researchers have suggested that the framework of a multifaceted socio-technical system is one that is non-linear, is complex and contains a level of uncertainty (Roberts et al., 2016; Pumpuni-Lenss et al., 2017; Foster et al., 2019). The heavy vehicle transport industry is one such system where the interactions, interconnections and interrelated functions all form part of that complexity. One where the decision-making process and constant adaption to changing and competing priorities between the varying components of the system often conflict or do not align with each other or with legislation, organizational rules and procedures. For example, the pursuit of generating an income often overrides the cost associated with being compliant.

Part of the complex heavy vehicle socio-technical systems comprises policies, rules, legislation and procedures to help guide the decision-making process and ensure both safety and compliance within the system (Laarson et at., 2010; Schobel and Manzey, 2011; Foster et al., 2019). The intent is captured in the legislation that governs the system where compliance to the legislation is required. However, the pressures and demands of the socio-technical system within which the heavy vehicle industry operates are compromised by stresses and demands requiring tradeoffs that expose those who operate within the system to non-compliance and potential failures (Reason, 1995; Quinlan, 2001; Quinlan and Wright, 2008; Jones, 2013).

Australia has legislation that identifies several layers of the heavy vehicle transport system that include the driver, the supply chain parties, heavy vehicle companies, government and regulatory authorities, all of whom have responsibilities under the legislation. This is not dissimilar to the legislation that is enacted in New Zealand (NZTA, 2009) that now allocates and requires actors, including customers, specific roles and responsibilities regarding what they must do to prevent a driver from committing a breach of their legislation. Canada have also implemented a road safety strategy that recommended drivers and in those involved in the heavy vehicle transport industry split their responsibilities (Canadian Council of Motor Transport Administrator, 2011).

The presence of laws, such as those found in the Heavy Vehicle National Law (2012) and the Road Traffic (Vehicles) Act (2012) and Regulations (2014), the latter being the Compliance & Enforcement legislation, help guide and influence the decision-making processes to develop the required rules, procedures and risk management processes to ensure compliance (Larsson et al., 2010; Schobel and Manzey, 2011; Foster et al., 2019). However, it has been said that the rules, laws and procedures can never account for all uncertainties and scenarios, so can never be sufficient for every context. Because the actors and the complex systems within which they work are multifaceted, suggests these rules, laws and procedures cannot cover all possibilities (Bagnara et al., 2010; Hale and Borys, 2013; Schobel and Manzey, 2011; Woodcock, 2014; Foster et al., 2019).

It is difficult to grasp how each level of the heavy vehicle transport system functions in unison with each other to create a system that is safe and ensures compliance by those within the system. The in-built complexity of the heavy vehicle transport system that arises from a multitude and variation of tasks, interconnections, interactions and interrelationships cannot be accurately and justly captured. This is simply because of the size and sheer numbers of those who are actively involved and connected within the system (Kleiner et al., 2015; Santos et al., 2016; Foster et al., 2019). This is more so relevant when endeavoring to identify and understand the links and underlying causes of a crash. The current approach to a driver centric focus must be stopped as the research suggests that post event evaluation of a crash recognizes that a nonlinear relationship exists.

The legislative frameworks, from a systems perspective, has been designed so that decisions made at the top level of the system such as policies and strategies for example, emanate from government and set the boundaries for safety within the heavy vehicle transport industry. The legislation identifies what is required of the heavy vehicle transport industry to be compliant (Anderson and Bailey, 2005; Farnsworth and McCarthy, 2016). It is also expected that decisions made by government and regulators cascade to the actors in the lower levels of the system such as supply chain actors, companies, owners and other networks for example, who implement internal policies to manage driver behavior and mitigate crash and injury risk.

Systems thinking

The core of systems thinking is that crashes occur as a result of behaviours in a system that do not work coherently together or as they are intended (Toft et al., 2012). Systems thinking is about the components of a complex system, being the interdependencies and interactions between integral actors that influence the behaviour and outcomes of other actor's behaviours within the system (Bosch et al., 2007). Recently, it has been identified that analytical methods and crash causation models, underpinned by systems thinking, as being the most prominent approaches for undertaking crash investigations (Grant et al., 2018). However, the safety process is not straightforward, driven by exchanges and relationships between actors, equipment and the environment (Underwood and Waterson, 2014; Salehi et al., 2020).

Salmon et al. (2012) and Salmon and Lenne (2015) conducted studies that found one of the key barriers in preventing a significant reduction in road crashes is focusing blame on the driver. Simply put, whilst the investigation continues to look for blame at the driver level, the opportunity is missed to identify other contributory factors and underlying causes from other levels of the heavy vehicle transport system (Newnam and Goode 2015; Newnam et al., 2017). Current investigation methodologies do not identify and provide an understanding why these incidents continue to occur as they do not identify system failures (Grant et al., 2018).

It is suggested that heavy vehicle fatal crashes continue to occur because there is an absence, as well as a lack of understanding, about the underlying causes of that contribute to these crashes. Greater understanding of why and how a crash occurs is fundamental to establishing interventions to prevent crashes from reoccurring (Rasmussen, 1997; Leveson, 2004; Toft et al., 2012). Rasmussen (1997) argued that it is essential to view a major incident as a complex process involving the entire socio-technical system. Rasmussen went onto further posit that the interrelationships and interdependencies lead to non-linear cause and effect outcomes. Rasmussen argued the it makes it difficult to predict the consequence of components of an action that occurs within a system as these components may be firmly linked and show little play in time and space.

Research has concluded that there is a need for investigations to look beyond individual actions to understand how a crash occurs so as to identify the underlying causes and to establish interventions that prevent the reoccurrence of a crash (Rasmussen, 1997; Perrow, 1999; Leveson, 2004; Leveson, 2012;

Stevenson, 2010; Dekker, 2011; Toft et al., 2012; Dell, 2015; Newnam and Goode 2015; Newnam et al., 2017; Dell, 2019; Cikara et al., 2020b). The research supports this stance and concludes that there are a myriad of contributing factors leading up to the cause of a crash, most of which are largely not considered or identified due to investigative methods that do not take these factors into consideration (Quinlan, 2001; Jones, 2013; Mooren et al., 2015). Research has acknowledged that driver behaviour at the time of a crash is important in identifying the pathway from the socio-technical system to the influencing factors that contributed to the cause of the crash, however most investigations stop at this point (Quinlan, 2001; Jones et al., 2003; Newnam et al., 2017).

In Australian studies conducted by Brodie et al. (2009) and Brodie et al. (2010) it was identified there was the necessity for implementing investigations to systemically examine contributing factors to a fatality rather than focusing on the driver. Researchers argued that investigations must identify the impact of decisions, actions or omission by other actors that influenced the driver's behavior and to establish the reasons and purpose of the driving task (Anderson and Bailey, 2005; Farnsworth and McCarthy, 2016). These findings are supported in studies conducted by Bugeja et al. (2007) recognizing that investigations into heavy vehicle fatalities needed to be improved in order to identify systematic failures.

It is acknowledged by Researchers that there are a number of factors that contribute to a heavy vehicle crash, however blame continues to be attributed to the driver (Quinlan, 2001; Jones, 2013; Mooren et al., 2015; Newnam and Goode, 2015; Cikara et al., 2020a; Cikara et al., 2020b) and that blaming drivers does not contribute to useful crash investigations or to improved safety outcomes (Rasmussen, 1990; Newnam et al., 2017). There is empirical evidence from a range of studies that conclude there are multiple factors that originate from organizational and operational influences that are outside of the drivers control that adversely influence driver behaviors and increase crash risk (Quinlan, 2001; Jones, 2013; Williamson and Friswell, 2013). Similarly, research conducted by Jones et al. (2003), Duke et al. (2010), Thompson and Stevenson (2014), Edwards et al. (2014), Mooren et al. (2014), Edwards et al. (2015) and Thompson et al. (2015) all support Quinlan's findings and concluded that economic and regulatory factors impacted and influenced driver safety.

Together these studies strongly suggest there is consensus that focusing beyond the driver's compliance to safety procedures is necessary and the lens needs to focus on management systems and the decisions and actions of other actors within the system such as Government and Regulators (Rasmussen, 1997; Leveson, 2004; Leveson, 2012; Toft et al., 2012; Newnam and Goode, 2015). A safe system depends on actors involved in the heavy vehicle transport industry working in collaboration, showing concern for the safety of others anticipating threats to safety, and contributing to safety improvements (Stucky and Lamontagne, 2005).

Conclusion

The evidence from the research suggests driving heavy vehicles in Australia, as well as in other parts of the world, is a dangerous and deadly occupation. The heavy vehicle transport industry operates in a complex socio-technical system that has many interconnections, interrelationships and interfaces at several levels, however the research suggest drivers are still being held accountable and blamed for the outcomes of a crash. To govern and ensure compliance Australia has implemented innovative legislation, albeit two different pieces with the same intent, to ensure that it is not just the driver who is held accountable or blamed when a crash occurs. The 'blame game' does not help identify where the system failed, nor does it contribute to improving the system. It simply removes the attention away from the factors that contribute to crashes occurring. In contrast the Heavy Vehicle National Law and Compliance & Enforcement legislation is designed to ensure system weaknesses are uncovered.

The research suggests there is a need to identify and implement a standardized investigative methodology, one that captures the system factors within the heavy vehicle transport industry linking to the socio-technical system. Whilst there are many investigative methods, not all are suitable. It is important the investigative methodology identifies all the actors that play a part in influencing and affecting the heavy vehicle driver's behavior.

There is limited consistent research that is relevant to investigations and underlying system causation factors that is focused on the heavy vehicle industry. The narrow research justifies the need for further studies to be conducted to explore this further. Additionally, based on the international context and varying scope of the research, there is opportunity to further explore international studies as well as investigative methodologies from other transport modalities and identify if there is potential to adopt and integrate these methodologies.

Overall, the studies recognize and support the idea that improved investigative methodologies, that are the same nationally, will improve the information being captured at crash scenes that can be analyzed to identify the underlying causes of these crashes and therefore improve investigative outcomes. The results of this study act as a starting point to inform international regulatory bodies of the importance in understanding socio-technical systems within which the heavy vehicle transport industry operates. This understanding will help investigators identify the underlying causes of a crash rather than focus their attention on the driver.

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