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Cover Photo

A BNSF (Burlington Northern and Santa Fe) Railway train carrying fuel exploded after colliding with an 18-wheeler at a level crossing around 6:45 a.m. CT just outside the city of Cameron, located about 75 miles northeast of Austin, on 23 February 2021.

The semi-truck did not slow down as it approached the railroad crossing, although the crossing arms were down and another vehicle was already waiting.

The BNSF train was carrying mixed freight. Of a total of 110 train cars, 13 derailed.

Luckily, there were no injuries to the crew or truck driver.

Retrieved from:
https://www.fox6now.com/news/train-explodes-after-colliding-with-18-wheeler-in-texas

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Article Submission

The World Safety Journal (WSJ) is a quarterly refereed journal (ISSN: 1015-5589) that includes original full-length papers, review articles and case studies on the most recent outcomes of advanced research in any occupational safety and health fields.

All articles shall be written in concise English and typed with a minimum font size of 12 point. Articles should have an abstract of not more than 300 words. Articles shall be submitted as Times New Roman print and presented in the form the writer wants published. On a separate page, the author should supply the author's name, contact details, professional qualifications, current employment position, a brief bio, and a photo of the author. This should be submitted with the article.

Writers should include all references and acknowledgments. Authors are responsible for ensuring that their works do not infringe on any copyright. Failure to do so can result in the writer being accountable for breach of copyright. The accuracy of the references is the author's responsibility.

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Human Factors in Systems Investigations of Heavy Vehicle Crashes at Level Crossings: Causal or Contributory?

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KEYWORDS

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Train
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Human Factors

ABSTRACT

Collisions at railway level crossings are the largest cause of Australian rail-related fatalities and are more likely to result in fatalities than other types of road collisions. An Australian Government review of collisions at level crossings found that the behaviour of motor vehicle drivers has consistently been cited as the most significant factor contributing to crashes at level crossings. This is supported by an analysis conducted by the Australian Transport Safety Bureau (ATSB) of collisions at level crossings which identified that the primary factor in almost every collision was the vehicle driver's failure to abide by the traffic control measures at the level crossing.

This study thematically analysed the findings of 17 investigation reports completed by the ATSB of crashes involving heavy vehicles and trains at level crossings. In most instances, the ATSB investigation reports identified heavy vehicle driver behaviour as the cause of the crashes. This analysis outlines the various human factor elements that the ATSB reports suggest contributed to the crashes and, in contrast, notes that these elements are the end result of an investigation that does not appear to go beyond findings and classification of human error to explore why these human errors occurred and contributed to the crash.

This study argues that the attribution of human error should be the beginning of an investigation not the end. While driver error was attributed by the ATSB as the primary cause of most crashes, it should not be considered as the primary cause but rather the outcome of a set of underlying factors and decision-making processes which, combined together, culminate in that error occurring. A number of these factors are influenced by the socio-technical system within which the heavy vehicle driver operates. Focus of effort is needed to investigate and analyse the prevailing circumstances and socio-technical system influences in order to discover the underlying factors leading to the human error.

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1. INTRODUCTION

Collisions at level crossings are the largest cause of rail related fatalities in Australia. While they are a relatively rare occurrences, representing approximately 1% of the national annual road toll (Larue et al., 2018b), level crossing crashes are more likely to result in fatalities than other road collisions and level crossing incidents are also more costly, with the estimated conservative cost of a fatality being at 1.9 million dollars (Di Milia et al., 2012). Research of all crashes that occurred at level crossings between 2000-2009 (Independent Transport Safety Regulator, 2011) identified that 50% of fatalities occurred at level crossings that were actively controlled, 25% occurred at passively controlled level crossings and 22% occurred at level crossings with unspecified or unknown controls. Most of these fatalities involved cars, utilities, vans and 4WDs, representing 72% of fatalities. 76% of those killed were male (ATSB, 2008).

The complexity of the socio-technical system within which heavy vehicle drivers are required to work adds to the risk of crashes occurring. Both the rail and heavy vehicle environment operate within separate complex socio-technical systems where humans and technology work together both with constituent parts that interact and are reliant on each other (Klockner & Toft, 2014). The two systems have different regulatory frameworks, infrastructure design and operating principles, procedures and practices. A failure to understand and apply the correct decisions at the right time can lead to a catastrophic outcome.

Level crossing design philosophy is based on the pretext that because of their mass and speed, trains are unable to stop abruptly and may take as much as a kilometre or more to come to a complete stop. So, in the case of active level crossings which are designed to alert road users that a train is approaching, it is the responsibility of the road user to observe the warning when it activates and stop their vehicle prior to the level crossing. However, in the case of some passive level crossings there are permanently fixed warning signs that warn the road user to stop or give way and look for approaching trains before proceeding across the level crossing (Mooren et al., 2015). At these level crossings it is entirely up to the road user to check for trains and ensure that it is safe to cross.

Most studies of level crossing crashes have focused on drivers (Read et al., 2021). There is, however, a distinction between incidents caused by driver error and those caused by the influence of socio-technical systems, both of which involve separate personal accountabilities (Vaughen & Muschara, 2011). For example, where a driver's decision not to stop at a stop sign at a level crossing is identified as the cause of a crash, there is a risk that systemic underlying causes may be missed when driver error is identified. The many factors that influence the driver's decision-making process are largely ignored, especially when information bias and assumptions infect the investigation process and fail to capture the systemic underlying causes. Dell (2015) stated:

> *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 (p.xv).*

Previous research suggests there is a disregard for the warning systems at level crossings and associated road laws by some motorists, including some heavy vehicle drivers. For example, the Labour Council of New South Wales (2001) postulated that drivers ignored level crossing protocols and Davey et al. (2008) found that heavy vehicle drivers consciously ignore the risks involved, with indifference towards their own safety and that of other road and rail users.

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Perrow (1984) found that failures in complex systems are inevitable and the occurrence of crashes with devastating outcomes is unavoidable. Although the rail environment to some degree is predictable, that is, the rail track remains constant and unchanged and the train runs along that track, the risk of a crash occurring at level crossings is out of the train drivers' control. However, the heavy vehicle transport industry is far less predictable as it relies on differing road conditions coupled with organisational and driver perceptions and behaviours, which has the potential to increase the likelihood of a crash occurring. Added to this are the unknown elements of driver behaviours which can be unpredictable and unavoidable, potentially influenced by other factors (Quinlan, 2001; Jones, 2013).

The train driver is reliant on the heavy vehicle driver stopping at the level crossing. Added to this are the pressures for governmental and organisational economies and competing priorities that erode safety systems and processes as a result of factors such as budget constraints, pressures towards cost effectiveness, design flaws, maintenance shortcomings, training and assessment, due diligence to name a few (Moura et al., 2017).

So, a far greater proportion of the responsibility for avoiding level crossing collisions sits with the road safety system and road users, including heavy vehicle drivers, who have the principal responsibility to ensure they comply with the warning systems and road rules related to level crossings to avoid collisions.

In relation to that compliance, evidence suggests that heavy vehicle driver behaviours are influenced by their company systems (Quinlan, 2001; Jones, 2013). For example, schedule pressure can lead to speeding or the failure to take rest breaks and can also influence driver risk-taking behaviours in general and in relation to level crossings (Mooren et al., 2015).

Vaughen and Muschara (2011) suggested that a deeper understanding of the causes of an incident, and ultimately making better and more effective recommendations for corrective action, can be achieved when investigative methodologies remove the emphasis of hindsight bias and push beyond the simple human error root causes (Manuele, 2014). Socio-technical system causes and weaknesses cannot be discovered when investigations stop looking beyond human error (Dell, 2015). There are a multitude of factors that are present long before a driver's journey begins and, in most instances, investigations do not trace back beyond the driver error (Dell, 2019; Cikara et al., 2020a). This omission fails to identify the systemic underlying causal factors of a heavy vehicle crash. Dekker (2006) suggested that human error is the effect or symptom of deeper trouble, with these sources of error being structural, not personal. To understand human error, one must examine the system within which people work. Numerous models and methods of analysing crash causation seek out multifactorial explanations as to why crashes occur (Naweed et al., 2019). Read et al. (2021) argued that collisions at level crossings are caused by both the decisions and actions of the level crossing users as well as the level crossing stakeholders, such as the rail companies, government and safety regulators and concluded that factors across the level crossing system interact to influence risk at level crossings (Read et al., 2017; Read et al., 2021).

A review of level crossing crashes completed by the ATSB (2008) found that 83% of all crashes, including passenger vehicles and heavy vehicles, occurred during daylight hours, excluding dawn and dusk. The ATSB findings identified that for most fatalities the point of impact was the front of the train. The ATSB findings also suggested this was because of drivers not noticing or misjudging the arrival time of an approaching train rather than not noticing a train that is already on the level crossing. Excessive speeds were not considered relevant in collisions with only 7% of all reported crashes involving speed. Unintentional road user error was identified as a major contributing factor in 46% of level crossing crashes compared with 22% of road crashes. In these instances, the driver has not seen

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the train, did not see or was unable to heed the warning system or for some reason was unable to avoid the train. Fatigue only accounted for 3% of crashes. Despite the findings in the ATSB report identifying factors why heavy vehicle crashes occur at level crossings this study identified there were 16 reports where driver error was attributed to the cause of the crash.

It has been suggested that the lack of progress on problem solving the reasons why level crossing crashes continue to occur is due to a lack of systems thinking during crash analysis (Salmon et al., 2015). When attempting to understand and improve level crossing safety a systems thinking approach has not been adopted (Read et al., 2013; Salmon et al., 2013b; Salmon et al., 2015). Investigations of level crossing crashes has primarily centred on driver behaviour which focus on components in isolation and does not allow the investigation to extend beyond the proximal causes (Salmon et al., 2015). While driver error has been attributed as the primary cause of most crashes, it should not be considered as the primary cause but rather the outcome of a set of underlying causes and decision-making processes combined together that culminates in that error occurring (Dien, 2007; Debrincat et al., 2013). These underlying causes can arise from any part of the socio-technical system. In most instances, error occurs at the point immediately prior to the crash occurring (Kee, 2016; NOPSEMA, 2020). This requires a detailed analysis to capture the points of failure leading up to the crash.

In the context of crash investigation and analysis, the socio-technical system needs to be considered in its broadest sense. The socio-technical system includes organisations and their systems (such as policies, procedures, design, engineering requirements), government (enforcement activities, audits, compliance activities, assurance and governance, adherence to Australian Standards), clients (meeting contract requirement, service demands and specific deadlines, contractual incentives, non-conformance to contract agreements) and the environment (such as weather conditions, road and rail design, vegetation, flora and fauna), which can all interact and influence the driver to either behave safely or make an error. A number of these factors are influenced and affected by the socio-technical systems. Risks associated with these factors are the responsibility of the business operators, regulatory agencies and government, not just the responsibility of the driver. Organisations must take these risks into account when managing driver's behaviours as do other actors in the socio-technical system. Incidents that occur do so because somewhere in the socio-technical system there was a failure to identify and control a risk. Knowing what those factors are, such as risk perception, inattentional blindness, fatigue, for example, helps with identifying the appropriate risk mitigation.

The human factors component is the end result of an investigation that does not appear to have applied a system thinking approach to identify why these human factors contributed to the crash. Human factors are only one element of the equation and should be the place where the investigation commences (Leveson, 2011; Debrincat et al., 2013; Dell, 2015; Doecke, 2020; NOPSEMA, 2020). What is important to consider is how did the actors in the socio-technical system influence driver behaviours that manifest themselves into human factors. For example, why was a driver fatigued?, what contributed to that fatigue? Was fatigue caused by scheduling pressures?, was the driver made to breach their driving hours?, if so why?, how was the drivers fatigue managed by their employer? All these questions point to a deeper level of the socio-technical system rather than sitting on the surface at the driver level.

The factors identified through the analysis reported in this paper focus on driver behaviours. However, the risks associated with these factors must be managed under the laws by the organisations that engage these drivers to undertake driving activities (Heavy Vehicle National Law 2012, Road Traffic (Vehicles) Act 2014 (WA)), thereby ensuring each actor in the socio-technical-system has a part to play to ensure risk is mitigated. For example, organisations must put in place safe systems of work to manage fatigue by ensuring drivers are taking rest breaks, the driving hours are in line with legislated

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requirements and drivers are fit for work. This is done through internal audits within the company to ensure compliance. Likewise, regulatory agencies which undertake audits to approve organisational fatigue management systems must audit the fatigue management systems to identify any non-conformance or gaps in compliance and ensure these are addressed by the company before approving the company to operate heavy vehicles. Government must implement laws that ensure the driving hours legislated do not increase the risk of fatigue. Should fatigue be identified as a contributing factor in a crash, each and every part of the system must be examined to identify if there was a failing in that part of the system, why that failing occurred and what caused that failing. The same applies for a driver's fitness to operate a heavy vehicle i.e., whether they are affected by drugs and alcohol, health disorders, mental well-being; their propensity to take risks, such as impatience at level crossings, driving too fast; their familiarity with an area creating complacency; journey management of a particular route, for example, what are the speed limits?, where are the level crossings?, how many level crossings are on the journey?, how long should the journey take?

This study reviews ATSB investigations of crashes involving heavy vehicles and trains at level crossings throughout Australia for the period 2000 to 2019 and looks at the human factors associated with the contributing factors identified in the 17 crash investigation reports completed by the ATSB.

2. LEARNING FROM CRASHES

Learning from crashes is critical in preventing a repeat of another crash and potential fatality. Lukic (2012) defines learning from crashes as a process through which employees and the organisation as a whole seek to understand any negative safety events that have taken place in order to prevent similar future events.

When crashes occur, investigations take place to identify factors leading to the crash (Moura et al., 2016). A systematic investigation and analysis of common causal factors, identified from the investigations conducted, will inform learnings about systemic issues that lead to level crossing crashes. These learnings will in turn inform industry and government decisions to reduce the risk of crashes from occurring. In most instances however, blame is focused on the driver (Newnam & Goode, 2015; Dell, 2015; Newnam et al., 2017; Cikara et al., 2020a; Cikara et al., 2020b).

Learning from crashes applies to both the rail and heavy vehicle transport industries, although information extracted from investigations does not always result in changes that would prevent a future reoccurrence. However, due to complex and dynamic interplay of organisational, social, economic and political factors, learning from crashes and implementing those learnings may be challenging (Rosness et al., 2012), especially when it involves dealing with two differing industries, government regulators and organisations.

An Australian Government House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government (HRC, 2009) reviewed collisions at level crossings between 2004 and 2008 and found that 'the behaviour of motor vehicle drivers has consistently been cited as the most significant factor contributing to crashes at level crossings' (p. 7). A 'Rail Level Crossing Safety Bulletin' issued by the Australian Transport Safety Bureau (ATSB, 2008), that reviewed investigations it conducted between 2006-2007 of collisions at level crossings, identified that the primary factor in almost every collision was the vehicle driver's failure to abide by the traffic control measures at the level crossing although there were many underlying factors leading to the collision.

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Baysari et al. (2008) suggested that it is essential the causal factors of level crossing crashes are identified to inform decisions regarding appropriate prevention or mitigation strategies. Toft et al. (2012) and Sochon et al. (2013) suggested that 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. 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.

3. AIM

The aim of this paper is to discuss the driver related factors identified in the analysis of the findings from 17 ATSB investigation reports of collisions involving heavy vehicle and trains at level crossings.

4. DATA SOURCE

Two sources of data were used – the academic literature and research of crashes involving vehicles at level crossings, and data extracted from the ATSB website rail safety investigation reports that are accessible by the public. The ATSB reports were downloaded and reviewed. The search of the ATSB data included full investigation reports as well as shorter succinct reports or bulletins that provided information on crash analysis and findings. The data from the ATSB investigation reports only included the contributing factors, being the primary causes of the incident and other supplementary causes described in the reports as being either 'other safety factors' or 'other factors that increased risk'.

5. INCLUSION AND EXCLUSION CRITERIA

For the purposes of this study, it is to be noted that there are a number of crashes that occur at level crossings which are not investigated by the ATSB. Some are investigated by other state based or federal government regulatory or investigative agencies. This study only reviewed investigation reports conducted by the ATSB. For example, the ATSB identifies in its 'Railway Level Crossing Safety Bulletin' (ATSB, 2008) that between April 2006 and December 2007 the ATSB investigated nine level crossing crashes involving heavy vehicles. In addition to this, state authorities investigated a further three significant crashes involving heavy vehicles and passenger trains. These three crashes are not included in this analysis.

6. METHOD

A literature search was conducted utilising online search engines that included the following databases: EBSCO host, ProQuest, Informit, Scopus, PschyInfo, OVID Medline, Embase, Web of Science TRID and Google Scholar. Searches were also conducted in relevant road safety and regulatory organisation websites associated with heavy vehicle safety. This included organisations that were national and international.

Search terms used included: crashes, level crossings, heavy vehicles, trucks, level crossing safety, level crossing crashes, heavy vehicle safety, coronial investigation of level crossing crashes, transport crashes at level crossings, investigation methods, heavy vehicle fatalities.

Academic literature, article/report was assessed for eligibility against two criteria, namely: (1) publication date must fall between the years 1990 and 2020 and must include (2) reference to the level crossing crashes. Thematic analysis was conducted to identify themes related to the underlying causes of level crossing crashes between vehicles and trains.

This research included the results from a thematic analysis conducted by the authors of investigations undertaken by the ATSB of crashes involving heavy vehicles and trains at level crossings between 2000 and 2019. The contributing factors that were in each report were collated, analysed and then grouped into themes. The supplementary causes in all reports were also collated, analysed and grouped into themes.

7. LIMITATIONS

A limitation of the study was the data source was confined to the ATSB investigation reports which are publicly available. It is likely these reports have been heavily scrutinised by key stakeholders prior to being released into the public domain, potentially changing the original content of the first drafts. Additionally, differences in the investigative process from 2000-2019 may also produce its own limitations as there may have been changes in practices, approaches, experiences and skill sets over these years.

8. RESULTS

The results of the thematic analysis identified there were 46 specific contributing factors and 76 supplementary causes reported in the investigations. Contributing factors are factors that are considered to be the primary cause or causes of the crash. Supplementary causes are additional causes to the crash which are not considered to be as significant as contributing factors.

The analysis of the 17 ATSB investigation reports found that driver behaviour was a factor in 16 of the crashes (94%). In 15 investigation reports driver familiarity with the area of where the crash occurred was identified. However only five investigations identified familiarity as either a contributing factor or a supplementary cause. There were 12 reports that identified the driver either failed to give way or stop at the level crossing for reasons such as being distracted, unaware or being preoccupied. In nine reports it was found that driver familiarity with the areas potentially created the low expectation of a train or that a train would not be present. Seven reports identified the driver did not drive with due care and attention and in two reports the driver did not drive to the road conditions.

In eight investigation reports the acute angle of the road to the level crossing was identified as a factor and in five investigation reports the design of the cabin of the heavy vehicle was identified as a factor. Five investigation reports identified that vegetation alongside the rail corridor or surrounding the level crossing likely impaired the drivers sighting distance along the rail track. In five investigation reports it was found the level crossing warning signals and level crossing warning markings were not compliant to the Australian Standards.

9. DISCUSSION

Research conducted by Kletz (1993, 2001, 2009, 2012) and Hopkins (2008) found that fatalities re-occurred as a result of the same sorts of incidents. These incidents continued to occur, not because the industry did not know how to prevent them, but rather because industry did not use the knowledge from the past that is available to learn from them (Keltz 2001, 2009, 2012). For those incidents that occur within the socio-technical systems between the rail and heavy vehicle transport industry it is important to identify the causal factors from both systems and learn from these crashes to inform future

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mitigation strategies to reduce risk of these crashes occurring (Salmon et al., 2013a). McSween and Moran (2017) argued that action plans must do more than just focus on "at risk" behaviours but rather concentrate attention on foundational root causes such as system failures.

Current research has remained focused on particular road user groups, in particular blaming errors and violations on driver behaviour without taking into consideration the socio-technical system factors such as the environment, design and operational context (Cornelissen et al., 2015). Key aspects of driver behaviour such as driver error, decision-making and situational awareness remain unclear (Salmon et al., 2013b) and the causes of level crossing crashes poorly understood (Lenne et al., 2011). Larue et al. (2018b) argued that risky behaviour at active level crossings is largely deliberate, with most violations being motivated by saving time or road users failing to stop at and deliberately driving through level crossings while lights were flashing. It was suggested that road users were preconditioned by past experience that level crossings would be closed for extended periods, so rather than waiting they breached the warning lights and proceed through the level crossing. This essentially rewarded the road user for their risk-taking behaviour, i.e., not wasting time waiting, arriving at their destination on time. This behaviour repeated over multiple occasions creates complacency and a lack of respect for the risks at the level crossing. Other factors identified by Larue et al. (2018b) that contributed to level crossing crashes included level crossing design and inadequate and inconsistent level crossing warning signage.

Review of the contributing factors and supplementary causes, identified in the cases from the ATSB investigation reports, point to the heavy vehicle driver behaviour as being the cause of the crash. This is supported by other research into crashes involving trains and vehicles where that research found that driver error rather than deliberate violations was primarily responsible for crashes that occurred (Baysari et al., 2008; Caird, 2002; Salmon et al., 2013a; Larue et al., 2018a). This study, as well as the research from other academics (Caird, 2002; HRC, 2009; Laapotti, 2015; Larue et al., 2018a), has identified that the actions, decisions or behaviour of the driver were to blame for the crash occurring. However, research has discovered other underlying causal factors such as obstructed sighting distances due to angles of the road to the level crossing or short sighting distances due to overgrown vegetation along the rail corridor, have also been linked to train crashes (Caird, 2002; Laapotti, 2015; Larue et al., 2018a). This is supported in the analysis of this study where it was found that the angle of the road as well as vegetation along the rail corridor and at the level crossing were factors in a number of crashes.

In addition to these purely instrumental factors outlined in the ATSB investigations reports, a number of significant underlying socio-technical system causes that need to be considered in order to understand the complete aetiology of the crash, as outlined by a number of researchers and as found in this study are discussed below.

Doecke et al. (2020) argued that human factors contribute to most crashes. However, Doecke also found that the system within which drivers operate should be designed to take into account human fallibility and interventions such as road improvements, better journey management planning and improved sighting distances, all of which could mitigate and reduce the risk of a crash rather than blaming the driver.

Research by Di Milia, et al. (2012) identified that:

> *according to several comprehensive reviews of driver behaviour at level crossings occurrences are generally a result of limited crossing/train visibility, inattention, distraction, lack of knowledge regarding level crossings and misjudgement of train speed or distance. However, a smaller, but unknown proportion of level crossing occurrences are due to deliberate violation of crossing rules (p.15).*

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While these findings were identified in investigations conducted by the ATSB, both the report by Di Milia et al. (2012) and the ATSB investigations do not extend into the heavy vehicle socio-technical systems within which a heavy vehicle driver operates. Additionally, motorists continue with risky behaviours which are reinforced when they continue with their journey uninterrupted over a level crossing with no negative consequence of a collision. This lack of negative consequence reinforces that risky behaviour (Di Milia et al., 2012). Other considerations that may affect driver behaviour includes visibility. This may be as a consequence of an impairment such as not wearing visual driving aides, obscured visibility from dirty windscreens or due to environmental factors such as road and level crossing design.

A thorough understanding of why human factors contribute to a crash is dependent upon where the human error fits within the chain of events (NOPSEMA, 2020). It should not be acceptable to attribute human error alone to a crash. Focus of effort is needed to investigate and analyse the prevailing circumstances and socio-technical system influences to discover the underlying causes leading up to the human error (Health & Safety Executive (HSE, 2008). Crashes occur because of a combination of causes, and there are a number of factors that influence driver behaviour, such as workplace factors, deficiencies in safety management systems, vehicle design, infrastructure design, lack of government and regulatory interventions and environmental conditions (Quinlan, 2001; Davey et al., 2008; Jones, 2013). In a study of the contribution of human factors to railway accidents in Australia, Baysari et al. (2008) identified that nearly all incidents in their study 'were associated with at least one organisational influence suggesting that improvements to resource management, organisational climate and organisational processes are critical for Australian accident and incident reduction' (p. 1750).

9.1 Fatigue

Studies have identified that fatigue is a factor in approximately 3% of railway level crossing collisions (Di Milia et al., 2012). Fatigue can also be a factor in a driver's perception and attention. It is therefore important, when investigating a crash, to establish the level of fatigue a driver was experiencing prior to a crash occurring as well as identifying the organisational process used to manage fatigue risk. It is a legislated requirement for organisations to manage a driver's fatigue and must establish systems to do so (Heavy Vehicle [Fatigue Management] National Regulation, 2012; Occupational Safety and Health Regulations, 1996). This may include in vehicle technologies, split system rosters, set rosters avoiding night-time driving and compliance audits. When investigating a crash where fatigue is suspected questions can be asked to establish the level of fatigue risk that may include, how long the driver had been awake, how much sleep the driver had had in the past 72 hours or how many hours has the driver worked in the past week. It is also important for organisations to consider a driver's lifestyle and any medical conditions where there are personal health factors that could contribute to fatigue such as sleep apnoea. The review of the ATSB investigations identified fatigue as a potential factor in one crash amongst the 17 investigation reports, however the cause and history of that fatigue was not investigated.

9.2 Inattentional blindness

Based on research conducted by Mack and Rock (1998) and Saryazdi et al. (2019), inattentional blindness is defined as being 'The failure to notice an object or event when attention is directed toward a primary task or target' (p. np). Saryazdi et al. (2019) argue that it could be particularly challenging for drivers to attend to objects in the environment that are not relevant to the driving task itself, resulting in diminished comprehension of the environment should the driving task become more complex. For example, a driver negotiating a bend, approaching a passive level crossing on an acute

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angle, deciphering poor warning signage, changing gears, braking and poor line of sight of the track. This increased cognitive load requires a driver to be specifically focused on a specific task that it increases the risk the focus fails to comprehend immediate risk (Saryazdi et al., 2019).

The analysis of the ATSB investigation reports identified one instance of inattentional blindness and seven instances of inattention, distraction, preoccupation and being unaware as a supplementary cause. An incident investigated by the Office of the Chief Investigator in Victoria where a truck collided into the side of a passenger train killing a number of passengers (Office of the Chief Investigator, 2009; Salmon et al., 2013a) identified two important factors. Drivers reported that in their experience on open roads, their focus narrows, and they believed that they were not fully aware of the entire environment around them. This can cause the 'in-attentional blindness' (blank stare) phenomenon where the driver fails to see an object because attention is not focused on it. In these circumstances, drivers cannot explain why they did not see what was visible due to performing tasks such as operating vehicles. These 'blank stares' can also be caused by low arousal levels where drivers become bored, or they have a low mental load. Their attention wanders and they cease to concentrate on the task at hand (Office of the Chief Investigator, 2009). This was identified in Queensland Coroners Court Coronial Finding of Investigation (QLD 2008/392 & 2008/393, 2016) where the coroner raised the question of why a truck driver did not see the flashing lights at a rail level crossing causing the truck to crash into a train killing two occupants in that train. The coroner stated:

> *Inattentional blindness is a human information processing phenomenon that emerges in human factor analysis in crash investigations studies. It occurs when a person does not notice an object which is fully visible, but unexpected, because their attention is engaged on another task; in stark contrast to not paying attention. This is a phenomenon that has arisen in other fatal rail crossing collisions (p. 18).*

While inattentional blindness is recognised as a risk factor in driving (Saryazdi et al., 2019) and in crashes at level crossings, the ATSB investigation reports did not review organisational safety management systems to identify if inattentional blindness was considered to be a risk factor.

9.3 Situational awareness and unintentional non-compliance

Situational awareness is a critical component of driving and is a concept that drivers and operators in complex socio-technical systems maintain awareness of their environment and what is occurring (Endsley, 1995; Salmon et al., 2013b). It is having knowledge of the driving task at a specific time and place within the socio-technical system, taking into account the interactions and interrelationships between the driver, environment and infrastructure (Salmon et al., 2011). It is an essential element when driving and can lead to unintentional non-compliance. This occurs where drivers, not aware of their environment and circumstances fail to notice or observe what is obvious, such as level crossing warning signals and breach that level crossing warning resulting in a crash (Lenne et al., 2011). Drivers who do not actively pay attention to the system within which they are driving, their environment and surrounding infrastructure may not cognitively comprehend the presence of the warning signals at a level crossing. Research conducted by Salmon et al. (2013b) and the Office of the Chief Investigator (2009) identified poor situational awareness as being a factor implicated in level crossing crashes. While drivers with differing levels of driving experiences have differing levels of situational awareness (Bolstad, 2001), other factors such as stress, pressures and familiarity can also affect a driver's cognitive ability to recognise the risks in the system within which they are driving (Quinlan, 2001; Jones, 2013; Cikara et al., 2020a).

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Salmon et al. (2013b) argued that situational awareness is not explored in investigations because investigative methodologies used have limitations that make it difficult to make appropriate assessment. Salmon et al. (2013b) went on to posit further that investigative methodologies used to investigate driver behaviours do not support the description or assessment of situational awareness.

9.4 Risk perception

Lack of risk appreciation occurs where drivers do not understand the risks posed by level crossings and do not consider traversing level crossings as being dangerous. In a study by Davey et al. (2008) it was identified that while heavy vehicle drivers generally displayed a high level of knowledge regarding level crossing compliance, they acknowledged heavy vehicle drivers frequently infringed level crossing laws. The heavy vehicle drivers cited a number of factors for this non-compliance that affected their risk perceptions. A unanimous complaint was that level crossings were not designed to be user friendly with heavy vehicles, where, in rural areas particularly, design faults and location choice caused difficulties with sighting distances and train visibility. Another complaint was that there were inadequate warnings of approaching crossings. The combination of these factors of deficient design and protection systems were cited as being responsible for a majority of unsafe driver behaviours (Davey et al., 2008).

9.5 Familiarity, complacency and expectation

The analysis of the ATSB investigation reports identified that familiarity was evident in 15 of the crashes. In nine reports it was identified that familiarity, along with the low expectation of encountering a train or that a train would not be present, was identified as a factor.

Risks arise with familiarity where this factor is associated with violations and crashes. An analysis of fatal crashes at level crossings in Victoria (Di Milia et al., 2012) found that 85% of the fatalities occurred within one mile of the home address. Di Milia et al. (2012) identified that drivers who use level crossings regularly develop expectations about train frequencies and the likelihood of encountering the train. When drivers do not encounter trains on repeated occasions, they then develop a low expectation of encountering a train at that level crossing. This then leads to complacency and reduction in attention and poor scanning. Additionally, local drivers may come to know train timetables for their area and build a mental picture of when to expect a train accordingly and as such their alertness is commensurate with the times consistent with their mental timetable. The report concluded that ‘greater familiarity with level crossings can reduce perception of risk and encourage drivers to engage in greater risk-taking behaviour’ (p.18). This is supported in research conducted by Beanland et al. (2017) who suggested that drivers become complacent when they know trains are rare.

Davey et al. (2008) identified that due to the heavy vehicle driving task, heavy vehicle drivers who constantly travel the same routes with high frequency become conditioned to the environment within which they are operating. This constant exposure coupled with low frequency of level crossing encounters with trains can create for the heavy vehicle driver the perception and conditioned learning that encourages complacency and creates the mistaken belief that trains would not be encountered. This constant exposure at the same level crossing develops a learned and reinforced complacency that manifests itself into poor driving behaviours.

In a study conducted by Beanland et al. (2017) it was suggested that past knowledge and experience guides the way we seek, explore and analyse information from within our environment that informs and influences our understanding of circumstances and situations. It has been argued that this reinforcement process delivers outcomes where the wrong decisions and subsequent actions can be a consequence of those past experiences. Simply put, a heavy vehicle driver who travels through a level crossing on multiple occasions without encountering a train will have that experience reinforced and consequently form the expectation that they will not encounter a train. Their vigilance levels then become diminished, and drivers then neglect to scan for approaching trains or make decisions that lead to them failing to stop at the level crossing.

Other trained behaviours that increase risk include drivers who rarely encounter trains at level crossings with low volumes then have the perception that they will experience few trains at other level crossings. This was raised in Coronial Findings of Investigation (QLD 2008/392 & 2008/393) of a fatal crash involving a heavy vehicle and train where the coroner noted that 'there is also the prospect that the truck driver's attention was affected by the low expectancy of encountering a train at the crossing and limited confidence in the significance of the lights given his experience a few kilometres earlier' (p.18).

9.6 Misjudgement of train speed and distance

The research found that it was incredibly difficult to judge the speed and distance of approaching trains and the time it takes for trains to arrive at level crossings. It was found that road users are likely to base the speed of trains on their experience with cars which in most cases are travelling slower than trains even though they may appear to be travelling faster. Research suggests that larger objects are perceived as moving more slower than smaller objects when in fact they are travelling at the same speed (Di Milia et al., 2012).

9.7 Non-compliance, deliberate risk-taking behaviour

While driver non-compliance with level crossing controls is a factor that contributes to level crossing crashes (Salmon et al., 2013b), it is important to establish why drivers are noncompliant rather than stopping an investigation process once blame has been identified. In some instances what seems to be driver non-compliance can be a consequence of unintentional noncompliance; for example, a driver failing to detect or comprehend the meaning of warning signals and inadvertently entering into a level crossing at the same time a train is approaching (Lenne et al., 2011). Salmon et al. (2013b) argues that a lack of situational awareness is more than likely 'at the root' of unintentional non-compliance by drivers at level crossings' (p. 196). The cognitive failure to be aware of the driving environment can be attributed to a number of factors including driver experience (Salmon et al., 2013b) and how drivers respond in particular environments.

On the other hand, there are those road users who, despite every effort to promote safe driving behaviours, experience frustration and impatience when required to stop at level crossings. There are also those drivers who deliberately accept and take risks as they believe the benefit for violating the level crossing controls will save time. It was identified that violations increased when the time between the activation of the warning signals and the train arrival was between 20-30 seconds (Di Milia et al., 2012). Impatience occurs when road users are in a hurry. It was found that there was a greater rate of violation occurring in the morning rush hour. The review of the ATSB investigation reports identified that drivers made deliberate decisions not to stop at the level crossings. When operating a heavy vehicle there are increased time frames to recommence acceleration and gain speed especially when loaded. It is probably why in one report it was found the driver was undertaking a rolling stop rather than completely stopping at the level crossing.

Davey et al. (2008) recognised that willful violations played a significant part in driver behaviours, this being a wilful disregard of level crossing and road rules. However, what was also identified were the influences that facilitated or contributed to that behaviour. It was identified that wilful disregard for the rules may have been brought about as a result of other influencing factors that encouraged risk taking. What was most prominent in influencing unsafe driver behaviour at level crossings was a desire to

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avoid delay in drivers getting to their destination caused by time delays stopping and waiting for a train to pass as well as the requirements to decelerate and accelerate. This was interconnected with time and scheduling pressures for drivers to meet tight deadlines imposed by their organisations that did not factor in potential time lost waiting at level crossings (Davey et al., 2008). Heavy vehicle drivers cited unrealistically rigid scheduling and punitive measures for noncompliance as primary motivating factors for risk taking. Such practices in the heavy vehicle transport industry have been identified as being instrumental in driver violations (Arboleda et al., 2003).

9.8 Driver lack of knowledge of the rules for level crossings

Another key point to consider is the driver's lack of knowledge of the rules for level crossings. Di Milia et al. (2012) identified that there is evidence that many drivers do not understand the road rules that apply to level crossings, particularly those rules that apply to passive level crossings. In research conducted by Rudin-Brown et al. (2010, 2014) it was identified that drivers' understanding and interpretation of the correct behaviour when encountering level crossing controls in a variety of states of activation are quite varied. For example, driver compliance at passively controlled level crossings was unexpectedly low. This is supported by Beanland et al. (2017) who suggested that, where drivers who are relatively unfamiliar with passive level crossing controls, may experience difficulty or confusion when negotiating that level crossing. This may be because they may be more familiar with an active level crossing and be searching for flashing warning signals to assist with their decision-making process.

9.9 Sighting distance and increased risk to heavy vehicle drivers

Australian Standard AS1742.7-2007 requires the sighting distance at a level crossing to be calculated based on the track speed for that section of track. It also takes into account the maximum viewing angle for the driver to be no greater than 110 degrees calculated based on the angle of the road to the railway track.

There were eight investigation reports that identified the acute angle of the road as a contributing factor to the crash, five identified the design of the cabin of the heavy vehicle as a factor and five investigation reports identified that vegetation alongside the rail corridor or surroundings of the level crossing likely impaired the drivers sighting distance along the rail track. The analysis also established there were 12 reports that identified the driver either failed to give way or stop at the level crossing for reasons such as being distracted, unaware or being preoccupied. In nine reports it was found that driver familiarity with the areas potentially created the low expectation of a train or that a train would not be present. The findings and contributing factors present questions. Did the familiarity of the area increase the driver's tolerance to risk or did the driver consider the risk of stopping and accelerating across a level crossing to be a greater risk instead of driving straight through?

This risk of stopping and accelerating from a stationary position was considered by the ATSB (2007) which found that in one crash the level crossing sighting distance was probably inadequate for a 53 .5-metre-long road train to clear the level crossing safely from a stationary start. The ATSB (2007) report concluded other level crossings controlled by stop signs may be similarly deficient and more was needed to assess the risk.

Di Milia et al. (2012) argued that should heavy vehicle drivers stop at level crossings their safety may be compromised because a heavy vehicle takes a long time to accelerate from the stationary position, travel over and clear the tracks. The time needed to do so is dependent on sighting distance, track speed, weight of the heavy vehicle, road conditions and other systems factors. Di Milia et al. (2012) stated that if the sighting distance is limited or insufficient a previously unseen train can potentially reach the level crossing before the heavy vehicle has crossed, even when a driver has done everything correctly. In support, Beanland et al. (2017) argued 'stopping completely may be problematic for some vehicles, such as heavy vehicles, which lose momentum and require considerable time to regain speed and clear the level crossing' (p. 217). Larue at al. (2018a) also suggested that heavy vehicles face extended risks at level crossings due to their longer configurations and reduced acceleration capabilities and that these factors need to be considered for heavy vehicle drivers when crossing passive level crossings.

This factor may be an explanation why, in some instances, drivers did not stop or give way at the level crossing, rather than it being a case of inattention, distraction, being unaware or being distracted. It may not be a simple case of it being driver error or a deliberate violation. Consideration should be given to the notion that the drivers behaviour could be based on a calculated risk. It could be possible the driver has considered the lesser of two evils. That is, the risks of stopping, based on past experience taking into account, the lack of sighting distances, the acute angle of the road, the track speed, the vegetation obstructing the sighting distance, the design of truck cabin, gradient of the road, gravel or bitumen surface, wet or dry conditions, all of which significantly affect heavy vehicle acceleration performance and have all played a part in the driver determining the risk of driving through a level crossing without stopping was, in their mind, less risk than having to stop and accelerate. Even if they do not see a train the historical data suggests an unsighted train may still impact with the heavy vehicle as it traverses the crossing (Di Milia et al., 2012). In a study completed by Davey et al. (2008) it was found there was consensus amongst heavy vehicle drivers as well as train drivers who agreed that factors such as impeded acceleration, size of trucks, lines of sight and angles of approach introduced a danger at level crossings over and above driver behaviour.

10. CONCLUSION

In order to identify common links as well as themes, this study reviewed 17 investigation reports into heavy vehicle crashes with trains at level crossings. This review focused on the contributing factors and supplementary causes and identified human factors associated with heavy vehicle driver behaviour as the causes of the crashes.

This study argues that findings that identify driver error should not be the end of an investigation but rather the beginning. While driver error was attributed as being the primary cause of most crashes in the Australian Transport Safety Bureau investigations, rather, it should be considered as the outcome of a set of underlying causes and decision-making processes that have combined and culminated in the driver error occurring. Driver error is influenced by multiple factors within the socio-technical system in which the heavy vehicle driver operates.

Investigations need to focus on analysing the socio-technical system in order to identify what has influenced heavy vehicle driver behaviour. This will require a systematic investigation methodology that examines all parts of the socio technical system, tracing back to where the sequence of events had commenced and ultimately resulting in a crash.

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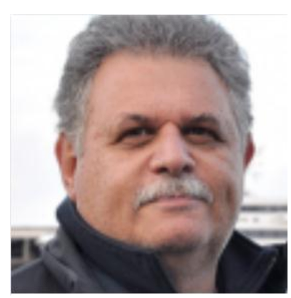

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ATV and UTV Injuries in Montana: Worker's Compensation Claims Analysis

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KEYWORDS

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ABSTRACT

This study investigated workers' compensation claims from 2007 through 2019, and distinguished all-terrain vehicle (ATV) claims from utility terrain vehicles (UTVs). The objective was to investigate accident and injury characteristics, patterns, risk factors and costs among both vehicle types. Data were provided by Montana Department of Labor and Industries, Montana Occupational Health & Safety Surveillance. The dataset contained 951 injury claims involving either ATV or UTV. The medical cost of these claims totaled $13,324,881 and wage loss totaled $4,681,404. Using chi-square of 95% significance, there were significant differences, p-value < 0.05, between vehicle types for part of body injured, cause of injury, nature of injury and cost. Findings can inform riders, safety professionals and employers about strategies to reduce loss of control events and resulting injuries.
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1. BACKGROUND

All-terrain vehicles (ATVs) and utility terrain vehicles (UTVs) are frequently used in the workplace. The modern ATVs were introduced in the U.S. in the 1970s as a three-wheel vehicle (Neves, Brazile and Gilkey, 2018), and were later replaced by the more stable four-wheeled design commonly used today (GAO, 2010). These vehicles consist of large, low-pressure tires, straddle-seats, and handle-bar steering (Neves, Brazile and Gilkey, 2018). Despite their popularity, ATVs are inherently unstable, relying on the driver's ability to shift their bodyweight to offset the tendency to rollover and thus risk-interactive (Jinnah, 2016). In a rollover event, ATV riders are exposed to head, spinal, and other serious crushing injury under the weight of the vehicle (Jinnah and Stoneman, 2016). The UTVs were introduced in 1988 as a safer alternative, with a lower center of gravity, bucket seats with safety belts, steering wheel, speed interlock, and roll-cage or survival space protection (Baker, 2014). Most ATVs were and remain designed to carry a single rider. In contrast, the UTV or side-by-side with bucket or bench seats are designed for carrying passengers. Some of the larger UTVs have both front and rear seats as well as storage capacity (Baker, 2014). The engineering changes over the years have made both ATVs and UTVs safer; however, these vehicles are not without significant risk to the operators and passengers (Gilkey, 2019).

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Several industries utilize these vehicles such as agriculture, construction, security, and search and rescue (Lagerstrom, 2015). The vehicles are used commonly for recreational and increasingly for occupational purposes. ATVs are used in farm work more frequently (hours/year) than for recreation alone (Khorsandi, 2020; Rodgers, 2001). Farm workers are more likely to have a rollover event or to be pinned under the ATV than recreational riders (Khorsandi, 2020; McIntosh, 2016). Recreational and agricultural work-related ATV crashes differ in their major mechanisms, resulting injuries, and speeds, suggesting that injury prevention approaches may need to be customized for each (Khorsandi, 2020).

There are an estimated 400,000 injuries that occur each year with nearly 100,000 ATV riders and/or UTV drivers that seek care in the emergency departments of hospitals across the U.S. (GAO, 2010). ATV fatalities reached a peak in 2008 with an average of 800 deaths per year (CPSC, 2019). The fatality rates have been declining in recent years linked to downturn in the economy, lagging sales, legislation, enhancements in safety features seen in UTVs, and available training for users. The popularity of UTVs is rising in part because of their safety features despite their higher cost. As recently as 2019 the UTVs are outselling the ATV 2:1 and the fatality ratio was an estimated 4:1, ATV to UTV respectively (Gilkey, 2019).

The majority of previous investigations have focused on off-road vehicle fatalities and not workers compensation injury claims or distinguished differences between the two types of vehicles and resulting injury. The Consumer Product Safety Commission (2019) reported that 15,250 fatalities have been investigated since 1982. The loss of life and injuries resulting from ATVs and UTVs use amounted to significant costs to patients, employers, and insurance companies. Helmkamp, Biddle, Marsh and Campbell (2012) estimated economic impacts of ATV related workplace fatalities between 2003 and 2006 to be greater than $100 million. Injuries to the back, spine, and head can have detrimental and lifelong effects. Very few studies have looked at workers' compensation claims related to occupational ATV or UTV injury cases (Lagerstrom, Gilkey, Elenbaas and Rosecrance, 2015). Investigators evaluated 212 claims from Montana from 2007 – 2012 and found "a statistically significant decrease in the number of ATV-related, emergency department-treated injuries in the years 2007-2012". The researchers also found fractures to be the most common injury, and rollover to be the most common loss of control (LOC) event (Lagerstrom, Gilkey, Elenbaas and Rosecrance, 2015).

The present study is a continuation of previous work and looked at injuries from Montana Workers' Compensation claims from 2007 through 2019 involving ATVs and UTVs. The aim of this study is to investigate 951 injury claims from the MT Department of Labor to describe and quantify the patterns, trends, cause, and nature of injuries, affected occupational sectors, and respective costs. Investigators were also interested in comparing similarities and differences between ATV and UTV claims.

2. METHODS

The claims data were extracted from a larger database of claims and were provided by the Montana Department of Labor and Industries, Montana Occupational Health & Safety Surveillance. The summary data were collected on February 10th, 2020 from the Montana Department of Labor and Industry Workers' Compensation Administrative Network. These data were derived from first report of injury (FROI) and subsequent report of injury (SROI) reports, which include information on the worker characteristics, accident factors, benefits paid, employer and insurer. Key words for inclusion were 'ATV', 'All-terrain vehicle', 'Quad-Bikes', 'UTVs', 'Side-by-Sides', 'Recreational Off-Highway Vehicles', and 'Off-Road Vehicles'. The extracted data contained 951 instances of injuries involving either ATV or UTV, a census of claims from 2007 - 2019. The summary data included 878 (92%) cases involving an ATV. Three instances were found to have been misclassified as ATV when they were UTV. Loss of control events were determined by manual review of accident description narrative reports. There were 799 (85%) LOC events on which the study focused. Of these, 749 (93.7%) were ATV crashes. The dataset contained 32 variables. Of these, several variables were redundant; for example, 'nature of injury type code' coincides with 'nature of injury type name'. Nine variables were dropped for this reason. Injury time contained an implausible majority (48%) of '1200', and thus was presumed to be a default response and was determined to be excluded. An additional two variables were created from manually reading the accident descriptions. Events were classified as Event Type; it was determined whether the crash was a rollover, non-rollover, ejection or unknown. Descriptions were written by claimants, not researchers, and could be uninformative, such as "ATV accident". These incidents were classified as "unknown". Then, each event was categorized into a cause of the crash, or common factors such as steep incline, collision with object, or sharp turn. All variables except Wage Loss and Medical Cost were categorical. Categorical variables were examined using descriptive and cross-table Chi-square analysis with 95% significance. Frequency of attributes in each variable was then examined to compare patterns and differences between vehicle types. Mean and median were used to compare financial data. Data were analyzed using R version 4.0.2.

3. RESULTS

The descriptive analysis reveals the ratio of male to female instances were similar between vehicle types, 639 (85%) were male for ATV and 41 (82%) were male for UTV. The age group 15-24 years was the most frequent for both groups, followed by 24-34 years. An employee was most likely to have a loss of control event in the first six months of employment, 37% for ATV and 44% for UTV. An accident was most likely to occur in the summer compared to fall, winter, and spring.

Table 1: Gender, Age at Injury, and Tenure

	ATV LOC (N=749)	UTV LOC (N=50)
Gender		
Male	85.3%	82.0%
Female	13.8%	12.0%
Age at Injury		
15 to 24	23.4%	26.0%
25 to 34	20.4%	20.0%
35 to 44	14.3%	20.0%
45 to 54	19.1%	14.0%
55 to 64	16.6%	14.0%
65 to 74	4.9%	2.0%
Undefined	1.3%	4.0%
Tenure		
Less than 6 mos.	36.8%	44.0%
6 mos to 1 yr	8.9%	8.0%
1 yr to 5 yr	25.1%	26.0%
5 yr to 10 yr	11.0%	8.0%
More than 10 yr	13.9%	12.0%
Injury Season		
Spring	19.1%	12.0%
Summer	49.0%	48.0%
Fall	19.1%	22.0%
Winter	7.2%	8.0%

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The industries with the most claims were Agriculture, Forestry, Fishing and Hunting with 63% of all LOC claims. From the descriptions, the most common activity among these was chasing cattle. The claims by industries can be seen in Table 2.

Table 2: Industries with ATV/UTV LOC claims

Industry	ATV LOC claims	UTV LOC claims
Accommodation & Food Services	0.9%	2.0%
Administrative, Support, Waste Management & Remediation	4.0%	NA
Agriculture, Forestry, Fishing & Hunting	63.7%	52.0%
Arts, Entertainment, & Recreation	2.0%	6.0%
Construction	3.3%	2.0%
Educational Services	1.3%	8.0%
Finance & Insurance	0.4%	NA
Health Care & Social Assistance	0.9%	NA
Manufacturing	1.6%	NA
Mining, Quarrying, & Oil and Gas Extraction	1.5%	4.0%
NOC	0.2%	NA
Other Services (Except Public Administration)	0.4%	2.0%
Professional, Scientific, & Technical Services	2.3%	2.0%
Public Administration	11.1%	14.0%
Real Estate, Rental & Leasing	0.5%	2.0%
Retail Trade	1.9%	2.0%
Transportation & Warehousing	0.1%	NA
Utilities	2.0%	2.0%
Wholesale Trade	1.6%	NA

Overall, ATVs had more rollover-associated injuries than any other type (43%) of all injuries. In contrast, UTVs had more non-rollover as the majority of injury causing events (62%). When looking at the occurrence of LOC events, rollovers were common for both vehicle types (50% for ATV, 48% for UTV).

Differences between the vehicle types appeared within the Nature of Injury (NOI). A contusion was more likely than a sprain or tear in a UTV incident, and vice versa for ATV. There were significant differences within Part of Body (POB) ($p = 0.005$). On an ATV, injuries to the back and chest were most common. While looking at UTV injuries, the extremities were most frequently injury POB. As shown in Table 3, back and spine was the leading body part for ATV injuries, regardless of LOC event type.

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Table 3: Part of Body by Event Type

	Rollover		Non-rollover		Ejection	
ATV	Back/Spine	24.7%	Back/Spine	18.2%	Back/Spine	28.9%
	Chest	12.7%	Wrist	14.0%	Wrist	10.8%
UTV	Back/Spine	6.0%	Hand/Finger	6.0%	Head	4.0%
	Internal Organs	6.0%	Neck	4.0%	Back/Spine	2.0%
	Multiple Lower Extremities	6.0%	--	--	Multiple Upper Extremities	2.0%

There were significant differences (p = 0.002) for Cause of Injury (COI). The most frequent COIs were riding on inclines, rough terrain, and/or collision with an object.

Table 4: Cause of Event

	Cause	Percentage
ATV	Incline	16.4%
	Rough Terrain	15%
	Collision W/Object	12.6%
UTV	Incline	22%
	Collision W/Object	14%
	Sharp Turn	14%

The present study shows some differences in NOIs between ATVs and UTVs. Table 3 shows that sprain or tear, contusion, and fracture are the three most common natures of injury for both vehicle types.

Table 5: Nature of Injury

	Nature	Percentage
ATV	Sprain or Tear	29.5%
	Contusion	25.4%
	Fracture	22.7%
UTV	Contusion	34.0%
	Sprain or Tear	20.0%
	Fracture	16.0%

A summary of the financial data, Medical Cost and Wage Loss, can be seen below in Table 5. Neither Medical Cost nor Wage Loss are significantly different (p = 0.47 & p = 0.45 respectively).

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Table 6: Medical Cost and Wage Loss

		N	Min	Q1	Median	Q3	Max	Mean
Medical	ATV	248	$202	$4,617	$14,329	$28,856	$4,849,679	$46,663
	UTV	16	$178	$2,525	$23,110	$39,643	$327,222	$43,988
Wage Loss	ATV	235	$19	$1,087	$3,863	$10,900	$218,904	$15,071
	UTV	16	$31	$1,070	$3,962	$14,633	$316,079	$38,389

If we consider medical cost to be an indication of severity and look at LOC instances greater than or equal to the mean, we can see that Back Including Spine is the most common body part injured for both ATV and UTV (32% and 75% respectively). The next most common are head (11%) and chest (8%) for ATV, and neck (25%) for UTV.

4. DISCUSSION

This research successfully identified patterns, characteristics, similarities and differences within the 951 claims provided for several variables of interest. The investigation was an extension of the first study by Lagerstrom et al. (2015) and included the sentinel comparison between ATV vs UTV injury claims. While there were many more ATV claims 878 compared to 73 UTV, investigators recognized differences in patterns and characteristics of injury work-related claims. The previous study by Lagerstrom et al. (2015) reported fractures as the most common injury type as did the present study. Similar patterns with some differences in NOIs between ATVs and UTVs. The investigative team found differences between the ATV vs UTV claims when looking at outcome in the context of LOCs, POBs, NOCs, and costs. This study is the first of its kind in comparing the workers' compensation claims of ATVs and UTVs, and in identifying which risk factors are common in each industry.

5. LIMITATIONS

This study has a number of limitations. The Workers' compensation claims were provided as summary data with recognized inherent information bias limitations. Possible errors may have occurred by the person filing a claim may not have known the distinction between ATVs (saddle seat, handlebars, etc.) and UTVs (bucket seat, steering wheel, survival space, etc.). Colloquially, many people may refer to all off-road vehicles as ATVs (Jennissen, 2016). There may be other misclassifications that could not be determined from the description. It is unlikely that this number would greatly affect our findings, as they were consistent with previous work (Lagerstrom et al., 2015).

6. CONCLUSION

Examining the injury claims can help us understand the differences and commonalities in the risk factors for both ATVs and UTVs. There were significant differences in part of body injured, cause, and nature of injury. Although there was not a significant difference in the costs, the difference in the number of claims is suggestive of an overall difference in safety.

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Haul Truck Automation: Beyond Reductionism to Avoid Seeing Turtles as Rifles

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KEYWORDS

Haul truck automation
Reductionism
Complexity
Artificial intelligence

ABSTRACT

Artificial intelligence offers a promising route to a sustainable future for the Western Australian (WA) Mining Industry, in which haul truck automation will play a pivotal role. The argument of this article is that the success of driverless technology hinges on the ability of artificial intelligence to embody the complexity of the world around it. The epistemology of automation is one of reduction. Reductionism has already applied practical constraints on the ability of intelligent machines to recognise dark faces, classify reptiles correctly, determine appropriate areas for policing and the likelihood of a criminal recidivism. The value position of artificial intelligence is one of prediction, and the machines' predictive capacity generally puts non-designed situations outside of its parameters, making its narrow and very bias view of the world appear to be more intelligent. This article argues that technology that is applied in a mining environment must embrace its intricacies, otherwise the Western Australian (WA) Mining Industry may miss the mark and witness similar examples of turtles being classified as rifles.

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1. INTRODUCTION

In a recent study of neural networks, researchers found that existence of adversarial imagery in real-world systems. The study manipulated patterns on a turtle to fool image classifiers into identifying the reptile as a rifle (Athalye et al., 2018). Neural network classifiers are vulnerable to conflicts in the physical world and remain open to varying perspectives. What this highlights is how artificial intelligent systems are operating in a pre- programmed view of the world re-arranged by the designer. Designers engineer artefacts by reducing them to their most basic parts. For example, the body, pattern, head and tail of a turtle are all stereotyped and fixed. Secondly, if it is process that we are trying to engineer, then the techniques are often analysed through time and motion studies. A great deal of 'science' is performed, determining what efficiency techniques should be standardised. Standardised methods provide the platform for automation, which attempt to lock-in the relentless repetition of that one best method.

Haul truck operations can be considered complex, where the constituent parts do not represent the function of the whole. In order to understand a haulage system, the process cycle is divided into component tasks: travelling empty, queuing at source, loading at source, travelling loaded and tipping at destination (Hamada & Saito, 2018). With technology becoming increasingly popular, researchers are raising doubts about the future of work in open- cut mining as technology is now capable of

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completing a large portion of truck driving tasks. For example, a driverless truck can drive from source to destination with what appears to be with limited interruption. What is not always known, however, is the localised adaptions that make driverless haulage possible. There are multiple supervisory roles working in the background to join the dots (Caterpillar, 2013). Connections are being made between what has been designed and what occurs in practice. That is because driverless systems are only as good as the designer's imagination of how each mining system functions. If we only allow engineers to develop this technology on a reductionist view of the world, driverless trucks will be less adaptive and restricted to innovative ways of working.

When technology systems are designed as expert systems, they run the risk of operating way out-of-context. While they were designed specifically for a workload or optimisation problem, their success has led to them being applied more generally. This has resulted in the product facing situations that are beyond its design parameters (McKinnon, 2019). Strict parameters may even lock in the biases and inefficiencies that steered the Western Australian (WA) Mining Industry to automation in the first place (Bellamy & Pravica, 2011). Industries are often drawn to automation to release latent capacity and to fix supply chain inefficiencies. However, more often than not, the algorithms simply compound existing methods and inefficiencies. The technology transforms the aspects that it was designed to substitute or replace. What was imagined to be a simple substitution of a driver for a machine, turned out to be rather complex. Users find that there are residual activities that cannot be completed by automated systems. Therefore, human supervisors are given a number of residual tasks to help the truck fleet navigate around a mine site (Caterpillar Global Mining, 2019). Moreover, despite the designed activities, there are also unspecified tasks with highly cognitive problem-solving aspects that automated systems are unable to resolve. As a consequence, what was once imagined as a like-for-like replacement, while reducing cycle delays and removing human exposure, ensued the creation of new strengths and weaknesses (Department of Mines and Petroleum, 2015a).

Haul truck automation has been adopted to respond to the increasing operating costs and for a reduction of human exposure to danger. However, this paper argues that engineering haulage cycle needs to go further to resist reduction and embody the complexity of physical mining. The design in application needs to revisit the many ways of transparency and explainability. If such focus is not given, then both safety and productivity will be compromised. There are numerous safety proposals that highlight the removal of people from danger. While others explain how the inattentional, fatigue and attitude-related aspects can be eliminated. However, before engineering a haulage system, the consequences and trade-offs need to be considered. In this research, the approach to reductionism, functional allocation and reconstruction of haulage systems will be explained, while offering empirical evidence of the impacts of truck automation within the WA Mining Industry-to date.

2. THE REDUCTION OF A HAULAGE SYSTEM

2.1. Simplifying the haulage cycle

A simplified haulage system represents a number of components that work seamlessly together to load, haul and dump. Reductionism distinguishes between what the system has and what it does, achieving simplicity through what it excludes. The practice also distinguishes between what humans and machines undertake as well (Dekker, 2014). The simplification of haulage systems rests on the belief that components operate independently, without non-linear interactions disrupting the flow of the cycle. This is achieved by breaking down the system into its most basic parts, re-allocating tasks to either human or machine (Pritchett et al., 2013). The system is then put back together again, with isolated components that operate independently. This enables engineering to contain incidents and serious breakdowns in the design of the haulage cycle.

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The reductionist approach aims to understand each components of the cycle individually within the system (Hamada & Saito, 2018). A simplified system improves upon knowing the behaviours of the constituent parts and being able to lock-in the productive methodologies for automation. It removes the variability and increases the predictability in what the system will perform. Haul trucks in a simplified system will therefore appear to be foreseeable and controlled in the way they execute the tasks. Therefore, trucks working within the design parameters will ultimately improve workplace safety and haul truck productivity. This constitutes the set of appearances that sit behind a much simpler haulage system.

2.2. Understanding truck driver contributions

Now that the system has been simplified to its most basic steps, haul truck activities within the system are analysed to determine the contributions of a truck driver. For example, a driver may enter the intersection, indicate left, turn left and then accelerate away. This is where the components, in isolation, unfold as expected without interruption. What is not always clear, however, is the types of interactions that are likely to occur on that intersection. There are various situations that could emerge, such as trucks entering the intersection, graders maintaining road conditions, or broken-down machines being recovered. A truck driver has various means of adapting to any of those situations. Firstly, the truck driver can follow priority rules and either proceed or allow other trucks to enter the intersection. Secondly, a driver is capable of communicating with grader operators via a two-way radio and requesting to make a pass around the machine. Thirdly, the driver can request permission via two-way radio to Mine Control to pass broken-down machines. Consequently, the ability of a human to analyse and adapt to a single example, such as this, makes reverse engineering truck driver contributions very difficult.

Despite the high levels of confidence in manufacturing how the brain and mind work, people learn and think by acquiring knowledge from one instance, not tens of thousands of examples (Lake et al., 2016). The ability of human to adapt, particularly in novel situations, is unprecedented. If a crusher is unavailable, a truck driver will call Mine Control to ask what is happening. Furthermore, a driver will ask to dump their load at a stockpile in order to keep the trucks cycling. Oncoming trucks observing the queue at the crusher, radio ahead and request to drive to another crushing location. On route, truck drivers may observe rock spillages and windrows that impede their travel path. The ability to classify objects and avoid them can often be taken for granted. Even in wet conditions, truck drivers have the capacity to observe wet roads and adjust to impeding conditions (Jamasmie, 2019). There are also experiences and lessons that have been learned and retained. For example, knowing that a ramp is made out of clay material and is widely understood to be slippery in wet weather. An automated truck cannot remember this information. Despite having driven over that particular part of the road numerous times before, driverless trucks will not retain the data for future reference. Trucks may even slide out of their lane on the same road multiple times. Therefore, without humans injecting smooth layers of adaptive performance, such as traction controls and avoidance zones (Caterpillar, n.d.), driverless trucks would continue to operate on haul roads as they would previously. By truly understanding the truck drivers' contributions, it can be observed how far technological advancement has come, and where it still needs to evolve.

3. ENGINEERING A HAULAGE SYSTEM

3.1. Technological advancement

Engineering a haulage system attempts to reverse engineer what activities manual haul trucks perform. It combines the understanding of the haulage cycle in loading, haul and dumping, with what we know

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about the human mind and brain. Without that intricate knowledge, the technology will just be making trucks available without optimising the circuit. Nonetheless, whenever automated systems are deployed, there is always a specific safety or optimisation problem that the user is trying to solve. For example, reducing driver delays, increasing truck availability or removing human exposure. Therefore, automated systems, at this stage, are all 'expert' systems. Expert systems require specific training data in order to program the execution of activities to be undertaken. Quite often, the training data came from the users themselves, with the technology simply replicating the knowledge that was contained within those facts and statistics. Earley (2016) explains how there cannot be artificial intelligent systems without high-quality sources of data. For that reason, driverless trucks are limited to the data sources that are collected, coupled with the intricate knowledge of the activities undertaken by truck drivers.

Data sources are now considered a key enabler for becoming an incumbent disruptor in industry (Araujo, 2018). However, data is not always free from biases, discrimination and may simply reinforce the problems of the past. Recidivism rates, for example, were based on how many arrests occurred in a particular area. Therefore, the technology simply redirected police to 'crime' where they were already policing (Lum & Isaac, 2016). Technology is recognising the patterns in a data set and compounding the information that is contained. With enough data, designers are able to recognise recurring themes and the common types of ideologies. Whether it is language processing (Hermjakob et al., 2018), computer vision (Brandt, 2017), robotics (Frohm et al., 2006) or self-driving vehicles (Goel, 2016), they all contain basic visual scene understanding, pattern recognition and the ability to recognise objects. That aside, there are other aspects, like the ability to communicate over the radio to pass another machine. Equally important, the ability to recognise the physical artefacts that surround the truck. LiDAR and Radar are capable of representing physical objects by bouncing light and radio signals, though it does not truly 'understand' those objects. Understanding dates back to the thought experiment of the Chinese Room. The experiment highlighted that if someone was given a set of questions in Chinese, followed those instructions to look up the required responses, they could appear to outsiders that they understood Chinese (Hermjakob et al., 2018). While this may be the case, this situation is very different to navigating real-world aspects that have never been confronted before.

Narrow-minded expert systems can be exposed when faced with non-designed situations. When automated systems are developed and tested against the data they were trained upon, automated systems can appear to achieve human level performance (Firmin, 2019). However, when faced with a novel situation or adversarial images, machines can operate beyond their context (Athalye et al., 2018). This may result in unintended interactions, misclassifying the object or not identifying the objects at all (Department of Mines and Petroluem, 2015b). Although technological advancements have made object detection possible, it is not there yet (Teichman et al., 2011). There are attempts to reverse engineer more human-like reasoning systems in machines, allowing them to become more adaptive outside their design parameters (Lake et al., 2016). Bridging the gap between science and engineering intends to increase our understanding of human intelligence, while figuring out the techniques to build human capabilities in a machine. The important part of this, is teaching the WA Mining Industry how driverless technology works, not just how to work it. To enable worker to better understand the computerised systems they work with, this can equip them with the inside knowledge to observe situations beyond the design and identify potential areas of overfitting.

3.2. Supporting roles, functions and tasks

The supporting roles of a driverless system are never conceived with humans in mind. Roles, functions and their tasks are leftovers from what engineers are yet to automate. The residual is based on technical limitations and the premise that human-machine capabilities are fixed (de Winter & Dodou, 2011).

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However, the strengths and weaknesses are never static; their abilities will co-evolve as people learn and technological systems are upgraded (Woods & Hollnagel, 2006). At the beginning, supporting roles are residual tasks that are allocated to human supervisors. The arrangements of the system are studied for what is contained (i.e. a truck driving from A to B), which excludes how the driver is deeply connected in how the system functions. For example, calling another machine to clarify whether a load unit is down for maintenance. Therefore, although supporting roles are given specified functions by design, the inability of a truck to think outside the box requires more human intervention than was once thought.

Functions are areas of responsibility that are found along the fringes of the role. Although a truck driver is expected to travel from load source to destination, they are also expected to communicate via two-way radio, identify hazardous road conditions and respond to emergency situations. The literalism of a machine agent, however, does not provide the same levels of insight to supervisors (Billings, 2018). The explainability for what a driverless truck performs can be quite low, which forces supporting roles to learn truck functions through observation. This can be observed in driverless trucks that perform a U-turn while waiting in queue to be loaded. While Mine Control may analyse the assignment engine to work out the reason for its actions, ancillary equipment operators can be left confused as to why the truck did not wait in line to be loaded. Where radio communications were used to advise others of truck movements, is now hidden among computerised interfaces and systems. Depending on access, roles and functions have different levels of access. It can also be difficult to determine the right level of information for the role, without inundating them with information they do not need or know how to interpret.

There are a residual set of tasks that have been developed by design. Uploading surveys, calling trucks to be loaded and verifying dump locations are examples of tasks created for support roles (Caterpillar, 2013). Human support roles play a critical role in ensuring the safety of driverless operations. The tasks support the verification of the virtual world to the physical world, a task that has failed to be verified correctly in the past (Department of Mines and Petroleum, 2014). This is where the processes between humans and machines become so important. Even though the process does not unfold in a predictable manner, support roles must have the foresight to prevent trucks from falling into sticky situations. A driverless truck, for example, may be attempting to achieve a reverse point that is located behind a windrow. Despite the dump being verified correctly, Mine Control may have simply corrected the face in order to become a straight line. Local adaptions are continuously evolving, adjusting and manoeuvring around danger that continuously emerges. The supporting roles, in effect, are now the eyes and ears of the operation.

3.3. Processes for supervisors and team members

Processes are instructions that enable people to work with driverless haul trucks. Those instructions are the tasks that provide the driverless operating environment or supply chain interfaces. Moreover, instructions are underpinned by the designers' imagination of operational practices. For instance, to mode change a truck, there is a sequence of steps to follow when executing the task (Glover, 2016). However, it is dependent on whether the task proceeds along predicable lines. The engineered component of that task theorises the truck responding to a person's requests. Its simplicity comes with the exclusion of the complexities that arise in real world applications. Designers are unable to plan for every contingency; therefore, they call upon humans to solve problems. Consequently, when a conflict between the design and the real world emerges, it is human adaption thinking outside the box that is required to close the gaps.

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Conflicts emerge when a person identifies truck function that is beyond the parameters. Despite the design allocating tasks to be undertaken by either human or machine, there will undoubtedly be unique situations. The paradox, however, is intervening to prevent a truck failure or intervening to cause a failure. This is the distinct situation that occurs in supervising automated systems. If a driverless truck is unable to achieve the reverse location at the crusher, supervisors would be expected to resolve the situation. Although the truck has been assigned that process by design, the unspecific creativity necessary to recover the situation will be novel and complex. Operational practices are a collection of individual experiences and external information. Nonetheless, automated systems offer little opportunities for people to practice their marginalised skills. Therefore, when those skills are called upon, people can perform dreadfully. Rather than debating deviations from design processes, leveraging the problem-solving aspect of human intelligence can enable supervisors to assist automated system navigate operational complexities.

3.4. Protecting the system from negative outcomes

Layers of protection are controls that are designed to prevent the system from failure (Willey, 2014). On the surface, the linear causal chain gives the appearance that the system is well protected (Glover, 2016). The assumption, however, is that the trajectories of workplace incidents are linear. The indirect sequence may not even commence at the top of the theoretical walls of protection. When the interactions are non-linear, interactions can arise from various angles, and those linear protections can become ineffective. Despite the layers of defense being engineered, automated systems are not known for their response to isolated failures. Rigorous fail-safe systems and test structures designed to insulate driverless technology, manufactured their own causal pathways that have mystified the WA Mining Industry (Department of Mines and Petroleum, 2014). No one would have imagined that a driverless truck would be unresponsive towards an impending truck collision (Department of Mines and Petroluem, 2015b). The consequences of engineering a complex system is that the outcomes are generated from complex interactions, not the failure of the individual components themselves.

Engineering more layers of defense only adds to the complexity of the system. Therefore, controls need to be applied diligently to not impose further opacity on the system. Protection may even need to be applied in areas where the gaps do not appear. The introduction of a new barrier simply creates a new opportunity for interaction. For instance, with the introduction of predictive path capability, even though manual equipment may not be heading for a truck's intended path, its potential direction and speed can project a collision. This can lead to the trucks engaging the emergency stop device, which can result in the travel lane breaches where they did not exist before. Although the diligence of high levels of protection, success depends on whether the system can withstand disruption and bounce back from novel situations. Control systems must move beyond literalism, becoming agile when compressed and stretched to their operating limits. The protection systems (i.e. LiDAR, Radar, emergency stops) designed to insulate people from human limitations (i.e. fatigue, concentration), appears to have introduced its own level of complexity through the reconstruction of the haulage system.

4. RECONSTRUCTING A 'SIMPLIFIED' HAULAGE SYSTEM

4.1. Team dynamics

When the system is eventually reconstructed, humans find themselves feeling out the trucks' operating parameters. The reactions attempt to figure out what the truck is capable of and when it will stop. For example, grader operators work closely to the truck's boundary to observe how the machine will respond. It is a game play often observe in teams, feeling out how far another player can pass or kick the ball. It is often known then, how far players should be placed in order to receive the ball. When it comes to machine agents, the approaches to replacing human work are rarely human-centric methodologies. Therefore, despite the specific training people undertake for their functional role, supervisors find themselves working out how machine functions in the workplace. This is due to the machine logic being hidden from the user, which claim to protect the vendors' intellectual property and stop the system from being overridden.

The storming phase is where the trade-offs and the frustrations occur since the replacement of truck drivers. Where manual machines could previously communicate directly with a truck, now requires a different line of communication. Communication involves selecting boxes, updating settings and typing instructions to inform the truck on what needs to be performed next. Moreover, it can also be difficult to get a machine to register what the human is trying to tell it. This is not just supervisors; it is the operators who have to work with the driverless trucks on regular basis. Excavators, for example, need to set a loading point with their bucket to enable trucks to identify where they need to reverse to. Operators are also required to press a button on their joystick to authorise awaiting trucks to enter the loading area. Where a truck driver previously self-spotted into the loading bay, now require the excavator operator to authorise their entry through a computerised system. Through practice, manual equipment operators working with driverless trucks learn what the functions the machine can and cannot perform. Often, it can be frustrating for users, who now need to complete tasks that were previously handled by truck drivers. On the other hand, the transfer of agency can be quite positive, allowing excavator operators to choose when a truck comes into the loading area. Overtime, mobile equipment operators learn driverless capability through their interactions with the system, identifying limitations and reactions to various situations. Although a screen interface helps with equipment separation, operators of manual equipment can activate a driverless trucks' proximity alarm. Until operators learn safe distances, manual equipment can frequently stop trucks by not knowing how to interact with them. In addition, a manned haul truck would remain outside another piece of equipment's 50 metre exclusion zone, making contact over the radio and asking for permission prior to entering their work area. As a consequence, manual operators interacting with driverless trucks go through a phase of working out driverless capability before they can begin to perform under these new circumstances.

The benefit of working with machine agents is the relentless repetition. Although there are complexities, the predictive path capability assists people to monitor the trucks' intended haul route. This also increases their level of trust towards driverless trucks. In a manual environment, it can be difficult to determine whether a truck driver will turn left or right. At times, truck drivers do not indicate or leave their indicator engaged, reducing the level of trust towards manually operated equipment. Contrastingly, human operators are given a level of security and control over driverless trucks. Each operator is given an emergency stop device that can stop all driverless trucks within several hundred metres. Once people identify recurring patterns and operating parameters of the trucks, they begin to perform more efficiently. Despite the positive performances observed with driverless trucks, the language and information outputs transform, resulting in a much more complex by-product to learn.

4.2. Learning what driverless trucks perform

Driverless technology is developed with the designer's best imagination of the system. What was previously controlled locally by truck drivers is now managed by a centralised control system. Where pre-shift briefings, radio announcements, safety meetings and return to works could articulate site-related matters to truck drivers, no longer exist. Alternatively, users are equipped with a standardised fleet management system that operates within specific operating parameters. The benefit of those parameters is that every truck performs each aspect of the cycle the same, yet the downside is they perform nothing else. Whether it is turning a corner, indicating or changing gears, the entire fleet will perform tasks the same way. Consequently, the same areas of the road are targeted, which results in corners and ramps deteriorating much faster. Since human supervisors have limited control over the driverless trucks' performance, they begin to adapt local practices within the operating parameters. This can be seen in installation of speed zones, which prevent trucks from changing gears on ramps and ultimately preserving road conditions for longer. As more capabilities and limitations are learnt, the more supervisors find creative methods of closing the gaps.

If engineers are the only architects of driverless technology, automation may only lock-in systemic ways of mining. Moreover, with multiple customers operating on the same parameters, the impact could be observed more broadly. If the designer is yet to figure out how to automate parts of the cycle, the system leans on ancillary equipment operators, supervisors and manual truck operations to cover the rest. Figuring out when a truck should leave a loading area is complex, therefore excavator operators are required to inform trucks by pressing a button. In addition, narrow work areas, such as stockyards, can require haul trucks to be operated manually. When it comes to supporting roles, trucks are unable to distinguish the difference in road objects. Therefore, the system relies heavily on humans to verify that the truck's travel path is clear before proceeding. A truck may have identified a windrow, tumble weed or even cattle. Supervisors have learned that reverse objects should be approached with caution, given that driverless trucks have reversed over waste dumps after being cleared to proceed (Department of Mines and Petroleum, 2014). Virtual and physical distinctions can result in trucks attempting to achieve dump locations regardless of context. Therefore, driverless trucks are unable to free themselves of machine literalism, executing specific instructions that are pre-programmed into the machine.

The difficult part about learning what a driverless truck can do, is that the logic behind a decision remains hidden. As a result, supervisors of driverless trucks learn by observing and doing. A supervisor can learn the patterns of a driverless truck by watching the reactions to machine interactions. In addition, people also monitor the assignment engine to compare with the trucks' instructions. Other than observations, the language and labels that are used must be learned in order to understand what the truck is trying to explain. The methods of communications are chosen by the designers of driverless systems, not the users themselves. Whether it is through alarms, beeps, lights and information boxes, they are all structured in unconventional methods that were previously experienced in a manual truck operation. Therefore, the learning process for users is evolutionary, as software systems are upgraded, and new product capabilities are developed. Supervisors will always compare driverless technology to human level performance, leveraging their domain expertise in how mining operations should function. Despite this, artificial intelligence systems like AlphaGo, may even find other methods of hauling that are worth exploring (Etherington, 2017).

4.3. Supervising and working with driverless trucks

The problem with working with a pre-programmed machine, is that they are not necessarily team players (Christoffersen & Woods, 2002). However, the WA Mining Industry has so far found driverless technology relatively good 'team players'. Driverless trucks run hard, play their role and do not complain. Moreover, supervisors feel empowered over the truck fleet, responsible for task allocation and capable of stopping the fleet at any time. The trucks will literally follow every instruction, re-assignment and take longer routes to achieve their objectives. However, it depends on the perspective. Although the trucks play their specified role, they also need a lot more support. There are residual tasks that are often unspecified, unpredictable and imbalanced. Supervisors can be completing monitoring tasks and simultaneously be confronted with network outages, truck slides and broken-down machines. This can quickly lead to fault-finding exercises in determining what has occurred and why. Monitoring the fleet can be long periods of inactivity, quickly followed up by highly cognitive tasks. Therefore, human improvisations rapidly materialise on the frontline; adapting, testing and playing in order to keep the trucks moving.

Supervisors of driverless equipment are often held accountable for the performance of the machine. If the machine did was it was programmed to do, there is only ever the supervisor who is to blame (McKinnon, 2019). In particular, if the situation was considered foreseeable, supervisors are expected to intervene to avoid negative events (National Transportation Safety Board, 2018). It is an interesting perspective when machines are not held to the same standard of accountability as supervisors. For example, if a truck's action resulted in an incident, yet the machine did what it was programmed, then the supervisor is held accountable. Supervisors are expected to monitor and detect failures that are unspecified and unpredictable. Available data is analysed retrospectively to highlight whether a supervisor could have intervened. However, with operating parameters rarely known by the supervisor, they can be left surprised when the machine simply hands back control. Automation surprises have been a phenomenon for quite some time (Sarter et al., 1997). Driverless trucks, for example, can be found driving the longest haul route to the crusher. To human supervisors, the action can be leave them amazed as to why the truck chose a further travel path. What is always not explained, is that if multiple network outages or obstacle stoppages occur along the direct route, the system eventually calculates that route to take longer. Therefore, a faster route is selected in order to get the trucks to their destination sooner. This prioritisation and decision-making process is not always explained without a prolonged analysis of the system. Supervisors are rarely afforded the time to reflect on the actions and insights that justify their marginalised roles in optimising the system.

4.4. Navigating beyond design situations

Situations that emerge beyond the design requires supervisors to think outside the box. The benefit of driverless haul trucks over self-driving cars is their ability to stop when faced with novel situations. For example, if a survey has not been uploaded for the area, the truck will not enter the area. Moreover, if the communication network is lost, the truck will stop. Self-driving cars, on the other hand, are not afforded the same luxury. The vehicle will hand back control to the driver regardless if the person is prepared for it (SlashGear, 2017). Navigating these situations in a mining environment is a little different, given that the landscape of the mine is always changing. Therefore, it is usually in the truck restart where the problems arise. For example, a truck detects an object while reversing to a tip edge, however it may not be an object at all. The object could simply be the windrow, with the reverse point being placed behind the windrow (Department of Mines and Petroleum, 2014). The truck would be unaware that the object is a windrow and should be the alternative dump location. Therefore, truck supervisor navigates this situation by physically verifying the location of the windrow and uploading a new survey. Without this type of adjustment, the trucks would attempt to achieve the location if the machine was cleared to proceed.

Since novel situations are infrequent, it is not often that recovery skills can be practiced. Monitoring automated systems has been argued to conflict with human cognition (Reason, 1990). Therefore, when humans are needed to intervene, they can react negatively. Despite this, the ability of a human to apply a level of unconstrained thinking to draw from external sources and experiences, reinforces why they remain. Operating parameters will continue to hamstring driverless trucks by design, given that a machine has pre-determined views of the world. While some simulations and games have multiple possible outcomes, all of the physical world's scenarios are unlikely to be computed. This is dependent, of course, on whether someone believes that the physical world is simply a simulation. If that were the case, simulation could simply learn to represent the artefacts of the world, making non-designed situations a thing of the past. However, as previously explained, this is a reductionist view of the world.

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Therefore, if human-machine systems are going to navigate complexity, many argue that they will have to work better together (Woods & Hollnagel, 2006). A more collaborative approach will have to allow information to flow freely between humans and machines. Currently, the focus appears to be more on replacing drivers to realise an economic value. This approach will ultimately lead to independent systems, which are ignorant of human-centered perspectives (Fridman, 2018). However, if engineers are to overcome complexity, driverless systems will need to become more open sourced and start working with other branches of science. Otherwise, driverless technology could end up in similar situations as other pieces of extended intelligence, becoming solutionist, opaque and bias in light of the customers' needs (Bleicher, 2017; Bolukbasi et al., 2016; Dressel & Farid, 2018).

5. CONCLUSION

Evaluating the approach to haul truck automation highlights limitations of reverse engineering a complex system. If driverless technology is to move beyond reductionism, it needs more than a collection of engineers to be included in its development. Otherwise, its deployment could experience similar practical constraints as other technologies, with an inability to recognise certain objects, incorrectly classify artefacts and predict outcomes based on stereotypes. What appears to be a truck functioning a particular way on the surface, could simply be a reinforcement of wider industry norms. Despite the industry buying this technology, they are not the custodian of the algorithms; they are merely the users. Therefore, mining companies have effectively handed over agency and their ability to innovate to vendors. Although the technology has reached enough engineering maturity to be deployed in a mining environment, there is far more to human intelligence. Drivers are able to recognise the physical elements and learn from the interactions that are had with them. Where operations were in directly controlled through truck drivers, is now managed by a centralised control system. The consequences can be observed in variety of settings where products target correlations and not causations. Therefore, to shift the industry paradigm, a diverse range of domain experts and product users need to assist design engineers to think beyond narrow and bias views of a mining operation.

The research highlighted various examples of reductionism in practice. Simplifying the prediction of criminal recidivism, foreseeing areas of crime and recognising objects. The predictive capacity and level of accuracy has been achieved by validating performances against data that is held out for testing. Therefore, as this study explained, when specialised technology faces non-designed situations, it relies heavily on human supervisors to overcome them. Although the technology can appear more intelligent than humans, this capability is achieved from what it excludes. As a result, haul truck automation has been no different, with the technology presented as a predictable and more accurate substitution for truck drivers. However, as significant incidents demonstrate, driverless technology has its own set of novel situations to resolve. If the industry is to truly work towards becoming safer and more productive, the underlying causes of incidents and inefficiencies need to be addressed, rather than simply running the system efficiently more unproductive. The industry must push for more open collaboration to enable users to establish new methods, ideas and products. More collaboration will enable the industry to move beyond the technological advancements of today and embrace complexity. As a result, the approach can avoid systemic tendencies, opacities and exploitations of inefficiencies that come with truck automation.

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Human Pose Estimation Using Depth-Wise Separable Convolutional Neural Networks

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Remote Rehabilitation

ABSTRACT

When it comes to dynamic human pose estimation, the process known as "identifying human joints in an image or video and determining their position in space" is used. This is done so that the dynamic position of the human body can be more accurately estimated and evaluated. This goal can be achieved by applying various computer vision strategies used in a number of industries such as gaming, robotics training, and animation. In this article, we propose a method for dynamic human pose estimation using convolutional neural networks (CNN). This method will soon be used as a form of physical therapy rehabilitation that can be performed in a remote setting. By making an assessment of the patient's postures, the physical therapist can determine whether or not the patient is performing the assigned exercises correctly. With this method, the physiotherapist can correctly adapt the therapy sessions to the progress that the patient is making in the recovery process.

1. INTRODUCTION

In recent years, the importance of technology as a factor in improving people's lives, especially in the field of medicine, has increased. This increase is due to the fact that technological advancements have facilitated the diagnosis and treatment of various diseases and injuries. This trend is likely to continue into the future; in particular, the development of immersive therapeutic applications, programs for the treatment of various diseases and injuries, has been facilitated by virtual reality that has paved the way for the development of such applications. These applications aim to increase accuracy of therapeutic interventions and reduce the severity of a variety of injuries and illnesses and associated symptoms by addressing them more precisely and in a targeted fashion. Thanks to the development of these mobile applications, patients now have access to information, rehabilitation and different types of treatment remotely.

This paper’s objective is to discuss progress toward the development of systems capable of guiding physiotherapy-related tasks on behalf of patients undergoing treatment in the comfort of their own homes. This system is based on virtual reality and its objective is to lessen the risk of injury to patients executing prescribed exercises incorrectly at home by providing them with feedback and instruction as they execute the exercises. These patients could benefit from using the system that allows them to continue with their normal day-to-day activities.

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Another purpose of this paper is to apply CNN to provide estimates of the human poses for a single individual. One of the reasons that these networks are so successful is that their organizational framework is comparable to that of a human's brain. Convolutional neural networks, more commonly known as CNNs, have swiftly risen to prominence as the method of choice for addressing issues related to image classification. This is due, in part, to the high degree of accuracy that CNN possesses. In a wide variety of object recognition tasks, CNNs have demonstrated astonishing levels of performance; this is due to the fact that network structures enable them to extract multiple levels of information from a single image.

2. BACKGROUND

Since 2014, and especially during the past six years, the use of and interest in Human Pose Estimation (HPE) has expanded, primarily as a result of the introduction of Deep Learning. From the initial rudimentary neural networks to today's complicated CNNs have significantly progressed. The use of filters to obtain lines, edges, silhouettes, and other distinctive characteristics of the elements contained in an image, as well as the ability to provide data to a system that can learn certain characteristics and then detect them when presented with a similar situation, have prompted a turning point (Badiola-Bengoa & Mendez-Zorrilla, 2021).

Typically, applications of pose estimation to rehabilitation following injury or surgery include the use of techniques to monitor an individual's return to normal movement patterns and to direct the motion of rehabilitation technology that is designed to interface with the patient. Pose estimation approaches have been utilized to evaluate and assess a patient's range of motion and movement during functional activities. Particular attention has been placed on using pose estimation to track rehabilitation progress outside of the clinic, such as at home or on the athletic field. In addition, numerous technologies have been created to actively interact with patients in order to either support their movement during therapy or offer a mechanical stimulus to improve rehabilitation outcomes. These technologies are usually referred to as rehabilitation robotics; methodologies utilizing pose estimation to guide the movement of these systems have been developed (Stenum et al., 2021).

The versatility of the technology, which is one of the most important aspects that contribute to its usefulness, has numerous applications within the optimization of human performance and safety, including injury risk assessment, rehabilitation, and performance enhancement. This application space typically involves an instructor, such as a coach, a trainer, or a clinician, who assesses an individual's movement patterns to determine whether the individual is for pathomechanical injury or delayed recovery. Two-dimensional pose estimation techniques, for instance, have been used to create proof-of-concept screening technologies that detect abnormal gait patterns during walking and running, fall detection, abnormal movements that are indicative of injury risk in manual labor work environments, and risk of sports-related injury, such as anterior cruciate ligament rupture. Post-injury analysis has primarily focused on sports performance applications and mechanisms of injury, with the end goal of developing strategies to reduce injury risk and restore normal mechanics, speed, strength and endurance to injured area (Stenum et al., 2021).

Human Pose Estimation can be carried out in a variety of ways; that can be broken down into two broad categories: techniques that begin at the top and work their way down, and strategies that begin at the bottom and work their way up the kinetic chain. When various strategies are categorized, they can be placed into either of these two categories depending on how they are ordered according to the individual qualities that they possess. Bottom-up algorithms, for instance, begin by estimating the position of each joint in the body (Cao et al., 2019; Pishchulin et al., 2016; Papandreou et al., 2018; Ning et al., 2017; Newell et al., 2017); this stage is the first step of the process. Once this stage is completed, algorithms proceed to the next stage, whereby the estimated joint positions are combined into a single pose. Once this stage is completed, the algorithms move to the next stage. On the other hand, top-down procedures (Fang et al., 2017; Moon et al., 2019; Chen et al., 2018; He et al., 2018) begin by identifying the person, and then determining the body joints of that person within the bounding boxes that have been identified.

3. WHAT IS POSE ESTIMATION?

Pose estimation is an artificial intelligence technology that analyzes images using machine learning algorithms. The idea is that neural network-based algorithms perform human pose recognition and body movement tracking in real time using a camera. The main applications of pose estimation technologies are as follows (Kalinin, 2021):

3.1 Fitness

When we think of automatic pose detection, the first things that come to mind are fitness, physique, and range of motion. Many startups are investigating AI capabilities for pose recognition. This technology enabled them to develop AI-powered personal trainers that assess how customers perform exercises and whether they require assistance in correcting their body position. Such fitness apps democratize personal coaching services by:

- lowering the cost of having a one-to-one professional trainer;
- lowering the risk of injury.

3.2 Physical Therapy

Another emerging trend in pose estimation is the development of physical therapy apps that detect body postures and provide users with feedback on specific physical exercises. Again, the benefits are:

- lower costs of care due to no or minimal physical therapist involvement;
- improved health outcomes for users;
- the ease of at-home exercise.

3.3 Entertainment

Pose detection software can also assist in the replacement of costly motion capture systems used in film and video game production. In video games, movement recognition can help create more immersive experiences. KINECT, for example, can use IR sensors to track the player's movements and relay them to its virtual avatar's actions. The benefits include:

- lower film production costs;
- improved user engagement.

3.4 Robotics

Another application of this computer vision technology is the control of robots. The rigid logic and movements of robots are replaced in this case by pose detection and estimation algorithms that allow for more flexible response. Positive features include:

- very little recalibration;
- rapid adaptation to a wide range of environments.

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4. HOW DOES POSE ESTIMATION WORK?

The basic idea behind pose estimation is to use machine learning algorithms, running on convolutional neural networks, to process RGB (aka normal, regular) or infrared (IR) images (Kalinin, 2021). Because many mobile devices and laptops have built-in cameras, RGB image-based pose detection is easier to implement than IR. Infrared images can be captured using KINECT and RealSense infrared cameras.

4.1 Skeleton Recognition

The neural network tracks the human body's major joints (e.g., knees, elbows, and feet) and then reconstructs a human skeleton and its movements based on its relative position and proximity of adjacent structures. Joint and corresponding body part positions correspond to various postures.

4.2 Bottom-Up and Top-Down Approaches

Pose recognition algorithms first identify a human when using the top-down approach. Following that, each human object is placed in a virtual box, and posture is assessed by tracking key anatomical points within the box. In the bottom-up approach, joints are organized into hierarchies and, eventually, skeletons; this leads to body position recognition and modeling.

4.3 Body Model

Before poses can be identified, CNNs require a well-defined body model. Simple kinematic body models have 13 to 30 points, whereas more detailed body models—mesh models—can have hundreds or thousands of points.

4.4 Pre- and Post-Processing

Proper pose estimation also necessitates image pre- and post-processing. Pre-processing may include removing the image's background and adding body contours (placing each recognized person in a box); geometry analysis is used in post-processing! Based on the findings, a fitness app with an AI assistant can advise users on how to improve their workouts.

4.5 Multi-Person vs. Singular-Person Pose Estimation

Multi-person pose detection is more difficult than single-person pose detection because a neural network must first successfully identify each person before evaluating and reconstructing his or her posture. Furthermore, people may block each other's views and interact in ways that make body recognition extremely difficult.

4.6 2D vs. 3D Pose Detection

Pose detection algorithms can perform 2D or 3D pose estimation. They estimate poses in an image in 2D and predict poses in an actual spatial arrangement in 3D. 3D pose recognition is more difficult because the background scene and lighting conditions must be considered and adjusted for optimal capture.

4.7 Images vs. Video

Pose detection from single images has already been established. The only difference between pose estimation from video and pose estimation from software is that software must decompile a video into a

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series of images; these images are then subjected to pose recognition processing. Pose estimation in videos has advantages because neural networks can see gradual or precise changes in posture and identify frames where specific body parts are visible (as opposed to frames with occluded body parts).

5. POSE ESTIMATION TOOLS

Pose estimations in 2D and 3D approaches require different toolsets.

5.1 Pose Estimation in 2D

Google has already developed specialized neural network architectures designed specifically for 2D pose estimation (see PoseNet below).

5.1.1 PoseNet

PoseNet is available from Google in two variants: single-pose detection and multiple-pose estimation. The PoseNet model works by taking an image from a camera as input and resizing it so that the model can run it. The model's next step is to output information on 16 body parts and compile them into a skeleton. Further, the model provides a confidence score for each pose, which can be thresholded to eliminate poses where the system is unsure about how to classify them.

5.2 Pose Estimation in 3D

Kinect or RealSense cameras are used to estimate 3D poses. They both have advantages and disadvantages.

5.2.1 Kinect

Kinect is a low-cost Microsoft camera for movement analysis that includes a depth sensor that captures depth data based on a video feed of infrared images. An Azure Kinect Developer Kit is required for the development. It includes hardware (the camera) and two Software Development Kits (SDK) for working with the depth sensor and body tracking algorithms. After installing the necessary libraries and prerequisites, the code from GitHub can be pulled and the pose estimation app can be developed. The demos in the GitHub repository, among other things, display information about joints by tracking body orientation and depth.

Among the advantages of Kinect are:
- the ability to estimate pose depth over a wide range (up to 5 meters)
- The body tracking algorithm is pre-trained on a large dataset and can output up to 30 frames per second.

5.2.2 RealSense

Alternatively, Intel's RealSense camera can be used. RealSense offers many of the same advantages as Kinect in terms of capturing high-resolution depth and color information, but at a faster rate — 90 frames per second. As a result, the output models move more smoothly. RealSense offers more than enough in terms of development. Their SDK, which is available on GitHub, includes a viewer, a depth quality tool, debugging tools, and many types of wrappers for integration with third-party libraries. Aside from that, they provide a standalone skeleton tracking SDK, with one drawback: it is not free! Positive features include:

- cross-platform (supports multiple language interfaces);
- No specialized hardware, such as a Graphics Processing Unit (GPU), is required to track multiple people.

6. METHODOLOGY

The first step in determining an object's pose involved loading an image into a tensor flow session and using a model weight to represent the object. Following that, the process of estimating an object's pose started. This session also included an architecture of a neural network, which was used to determine how the layers of the network were to be organized, as well as the weights that were saved during the processing of the pre-trained model.

Five crucial components made up the open pose pipeline, all of which collaborated to form the entire system. An algorithm generated a two-dimensional map of important anatomical locations for an individual based on the input image and its specific dimensions of width and height. This image represented the individual who was depicted in the input image. In addition, the width and height of the input image were specified. The system made use of a feedback network to estimate the 2D confidence maps of the body parts, which were denoted by the letter S. Additionally, the system made use of a feedback network to estimate the 2D vector fields that encoded the body parts, which were denoted by the letter L.

A J map of confidence was provided for every component in the set s = "S_1, S_2... S_J,", as shown below:

$$S_j \in R^{w \times h}, j \in \{1 \ldots J\} \quad (1)$$

Every item in the set L= L_1, L_2, L_C was represented by one C vector field; the fields were denoted by:

$$L_C \in R^{w \times h \times 2}, c \in \{1 \ldots C\} \quad (2)$$

In the end, greedy inferences were used to research trust maps and Part Affinity Fields (PAFs) so that 2D skeletons of the people in the input image could be made.

After the input image had been processed using the VGG-19 algorithm, it was then possible to obtain the F-maps. Following this, the two divisions then yielded the PAFs and the confidence maps, simultaneously.

As shown in Figure 1, the architecture was composed of two phases; each phase had two branches. The beige branches developed the confidence maps for each succeeding phase, while the blue branches prepared the PAFs for each phase. When the finished products were combined with the inputs, they yielded a single output. The forecast was modified at every stage to account for every phase's specific loss value; this was done because the process consisted of several stages, as well as intermediate monitoring stages. In the context of this research, the loaded graph was broken down into seven different steps.

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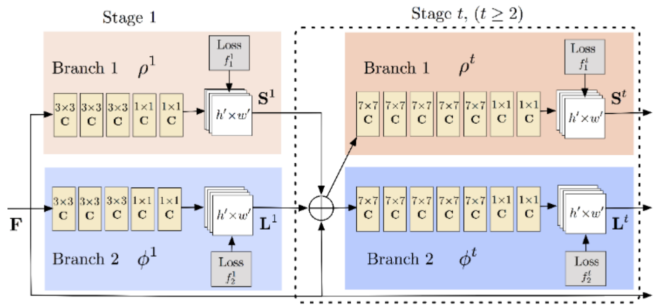

Figure 1. Architecture of the 2D Pose Estimation Model

A group of confidence maps, denoted by S_1, and a set of PAFs, denoted by L_1, were produced during the first stage of the process. The connection between the two stages is shown below:

$$S_1 = p_1 (F) \quad (3)$$
$$L_1 = \phi^1 (F) \quad (4)$$

The equations shown below were used to figure out S_t and L_t for the next phase.

$$S_t = p^t (F, S^{(t-1)} L^{(t-1)}) \ \forall t \geq 2 \quad (5)$$
$$L_t = \phi^t (F, S^{(t-1)} L^{(t-1)}) \ \forall t \geq 2 \quad (6)$$

One L_2 loss function was applied to each branch. The following equations provide an explanation of how the loss function operates when both branches are in stage t (Cao et al., 2019):

$$f_S^t = \sum_{j=1}^{J} \sum_p W(p). \| S_j^t(p) - S_j^*(p) \|_2^2 \quad (7)$$
$$f_L^t = \sum_{c=1}^{C} \sum_p W(p). \| L_c^t(p) - L_c^*(p) \|_2^2 \quad (8)$$

where S_j^* is the confidence map, L_C^* is the ground truth part affinity vector field, and W is a binary mask, with W(p) = 0. The primary function was broken down into the following categories:

$$f = \sum_{t=1}^{T} (f_S^t + f_L^t) \quad (9)$$

A subset of CNNs, known as depth-wise separable convolutional neural networks (DS-CNN), was applied for image processing. This process was broken down into five steps, see Figure 2.

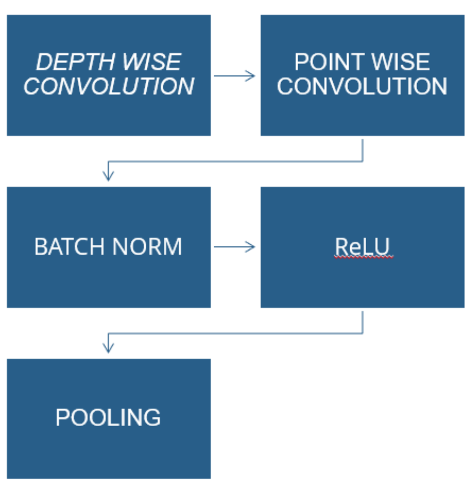

Figure 2. Pose Estimation Using the DS-CNN Process

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The layers consisted of the following components:

1) **Depth-wise Convolution**: This method applies a convolution to only one channel at a time, in contrast to the standard CNN method, which applies the convolution to all of the channels at the same time. The depth of the convolution is determined by the number of channels in the image. This allows for a greater overall reduction in the complexity of calculations.
2) **Pointwise**: In this step, one combines the outputs of the depth-wise convolution into a single result by applying a 1 x 1 convolution. This step is called "pointwise" convolution. This operation is carried out immediately after the depth-wise convolution is completed.
3) **Batch Norm**: The goal of this operation is to hasten the process of training while simultaneously lowering the risk of overfitting, as a consequence of the regularization process. This is accomplished through the use of a batching technique. This normalization strategy is implemented at the level of individual batches of data, as opposed to being applied to the entire data set, in order to save time.
4) **The Rectified Linear Unit** (ReLU) is a type of linear function that always returns a positive value regardless of the value given as input. This characteristic sets it apart from the various other types of linear functions. If the input is greater than zero, then the output will also be greater than zero; if not, it will be set at zero. If the input is zero, then the output will always be zero. However, if the input is greater than some predetermined limit, then there is a linear relationship between the independent variable and the input: f (x) = 0 if x is less than zero, and x if x is equal to or more than zero.

$$f(x) = 0 \text{ if } x < 0, \text{ and } x \text{ if } x >= 0 \tag{10}$$

5) **Pooling**: The pooling layers of the feature map provide a summary of the features that can be discovered in a particular region of the feature map. One of the goals of the pooling layers is to cut down on the number of parameters that need to be learned.

7. EXPERIMENTS

7.1 2D Pose Estimation

As a first input, we started by displaying an image at the start of the session. A total of about 0.2 seconds of time was required to arrive at a rough estimate of the 2D pose. Next, we provided a video as a contribution to the process that was to be followed. To get a 2D pose estimate, it took an average of 0.2 seconds to 0.03 seconds. The result obtained in both of these circumstances is shown in Figure 3, which is a skeleton with landmarks that connect the significant points of the human body. This result was achieved in all the different scenarios that were studied.

Figure 3. 2D Pose Estimation of an Avatar in an Image Input

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7.2 3D Pose Estimation

During this experiment, we went from a two-dimensional to a three-dimensional process and were responsible for distributing data across sockets. This procedure took approximately 0.7 seconds, with a margin of error of 0.1 seconds on either side of the estimate. The outcome of this scenario was determined by the degree to which a single image was repeated over multiple frames. If the image was already present in the previous frame, the procedure took much less time to complete because the data had already been roughly calculated. If the image was not already present, the procedure took the same time to complete. The result of this process is presented in "Figure 4," whereby the sent array had an estimated Z coordinate, in addition to the X and Y coordinates that were already there.

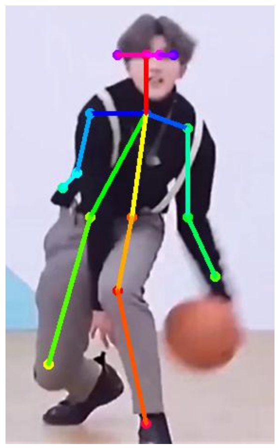

Figure 4. Incorrect 2D Pose Estimation

7.3 Pose estimation under different situations

Estimating a person's posture is a difficult task. Therefore, it was of the utmost necessity to test our method under a variety of variables and situations. Due to the fact that this technique is intended for physiotherapy exercises involving numerous complex movements, the information needed to be exact.

1) **Front Body View**: This process provided a view of the front body, along with the number of joints that were detected. The results are presented in Figure 5.

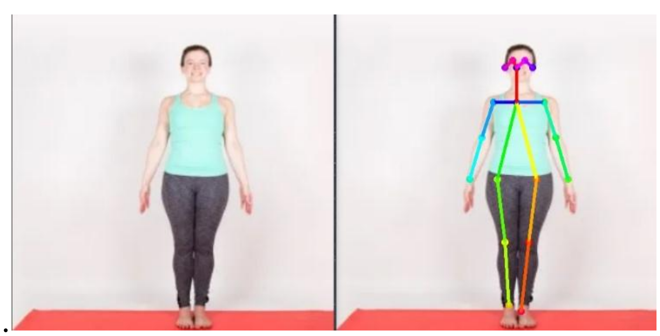

Figure 5. Input vs. Result of the Pose Estimation of a Front Body View Image

2) **View of the Body from the Side**: This approach gave a perspective of the body from the side, along with the number of joints that were detected. The results are presented in Figure 6.

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Figure 6. Input vs. Result of the Pose Estimation of Side Body View Image

3) **Pose Estimation for Multiple People**: This process provided a view of pose estimation for multiple people, along with the number of joints that were detected. The results are presented in Figures 7 and 8.

Figure 7. Input vs. Result of the Pose Estimation of a Multi-Person View Image

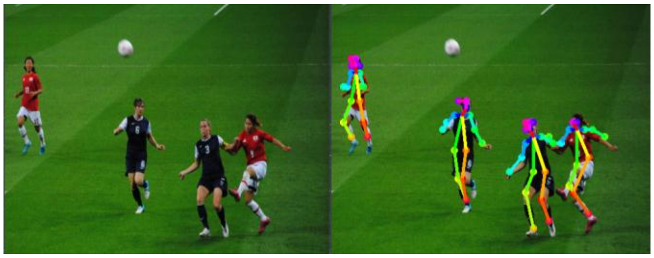

Figure 8. Input vs. Result of the Pose Estimation of a Multi-Person View Image

4) **Angled Body View**: This approach gave a perspective of pose estimation for an angled body, along with the number of joints that were detected. The results are presented in Figure 9.

Figure 9. Input vs. Result of the Pose Estimation of an Angled Body View Image

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5) **The Gaussian blur effect**: A gaussian blur effect was applied to an image to determine how well the system worked. The results are presented in Figure 10.

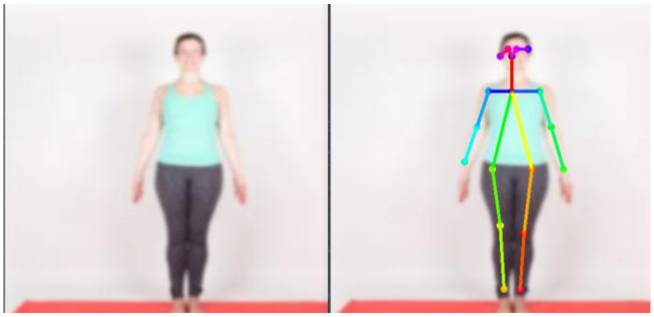

Figure 10. Input vs. Result of the Pose Estimation of a Blurry Image

6) **The Gaussian noise effect:** A gaussian noise effect was applied to an image to determine how well the system worked. The amount of noise, as well as the strength of the noise, were both adjusted to a value of 30 pixels. The projected number of joints and poses decreased when the noise values were greater than or equal to 30 pixels. When a significant number of noise pixels existed, the process of pose estimation did begin, and consequently no results were displayed. The results are presented in Figure 11.

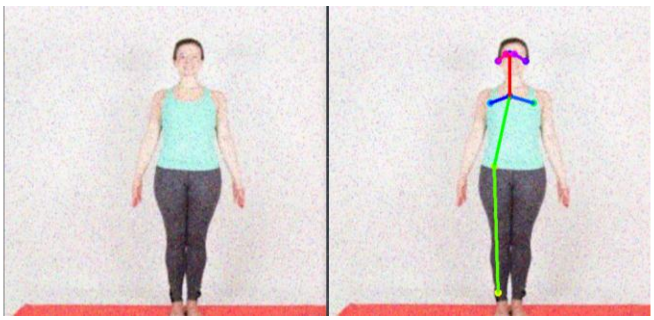

Figure 11. Input vs. Result of the Pose Estimation of a Noisy Image

The results of the different scenarios under study are presented table 1.

Table 1. Pose Estimation for the Different Scenarios

Scenario Number	*Total Number of people*	*Estimated joints*	*Incorrect Key Points*	*Missing Joints*	*Processing time (seconds)*
Scenario 1	1	17	0	0	0.45
Scenario 2	1	14	2	3	0.47
Scenario 3 (1)	5	0-8-0-7-11	0	17-9-17-10-6	0.8
Scenario 3 (2)	4	17-17-17-17	0	0	0.65
Scenario 4	1	9	0	8	0.5
Scenario 5	1	17	0	0	0.45
Scenario 6	1	9	0	8	0.48

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8. ANALYSIS OF THE RESULTS

When using the method described in this paper to determine someone's pose, the viewing angle is crucial. This has an impact on how the position is perceived. The perspective of the observer determines the angle of the scene; previous studies from hypothetical circumstances support this claim. Table 1 above omits crucial information, which contributes to misjudging the position. This is illustrated by how the location can be misjudged if certain body parts are hidden.

When an image exhibited a high degree of noise, the algorithm produced no data or results. The noise wiped out virtually every pixel in the image, thus removing many crucial body parts. When it comes to the degree of precision that an estimate can achieve once presented, the quality of the information provided plays a decisive role. Despite the limitations, the method we used was able to accurately predict the position of a substantial fraction of key points in the vast majority of cases. On the other hand, the algorithm was unable to reliably predict the location of specific joints because it could not identify them in the input image.

9. CONCLUSION AND FURTHER RESEARCH SUGGESTIONS

In this paper, we have introduced a method for implementing depth-wise separable convolution for pose estimation. Due to this convolution, depth information was differentiated from posed information, despite the fact that it struggled to deliver a result under certain conditions, such as when the angle of view is challenging or when the quality of the input is low. Based on the results of the tests, the method described in this paper can be used to estimate the pose of one person or many people.

As we move forward with this project, one of the key concerns will be to ensure that the proposed method is precise and efficient. We see great prospects for the continuous maturity and validation of the proposed method to provide strong complements or alternatives to subjective visual motor assessments and to increase the accessibility of measurement of movement kinematics by removing long-standing restrictions. The capacity to acquire quantitative, whole-body kinematics using a household device could significantly reduce reliance on inaccessible or data-limited older approaches, such as pricey research-grade motion capture equipment or wearable devices.

We see great promise for this technology applied to understanding injury mechanisms and rehabilitation, as well as occupational ergonomic analysis to identify and eliminate or reduce risk factors for work-related musculoskeletal injury. We believe that occupational safety and ergonomic professionals should embrace new tools and technologies to protect workers and prevent injury, pain, suffering, and associated losses.

The endeavor conducted in this study for dynamic human position assessment via convolutional neural networks (CNN) could be employed as a remote-accessible type of physical therapy rehabilitation. By looking at the patient's posture, the physical therapist can tell if the patient is doing his or her exercises in the right way.

Using the so-called immersive technologies, which have demonstrated promise in a variety of therapeutic fields, the endeavor described in this paper seeks to provide a solution to physiotherapy problems. The immersive environment in which the exercises would take place is a replica of the physiotherapist's office. This scenario is formed by a physiotherapist-installed network of multimedia sensors that would collect data from the clinic. In order to achieve the desired outcomes, the training session will be led by an avatar representing the physiotherapist, who will execute the identical exercises in real time. This method increases the patient's involvement with the physical therapist and

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decreases the likelihood of improper training execution. Augmented reality will be added to this interface to help keep the patient safe and guide him or her toward more useful activities.

In addition, we intend to establish a dashboard for the physical therapist that will enable him or her to diagnose patients and alter their exercises depending on ongoing developments and the outcomes of past office visits. However, this interactive simulation that makes use of virtual reality and augmented reality technologies does not replace actual visits to the physical therapist's office; rather, it serves as a supplement to lower the chance of rehabilitation failure. The instrument is designed to be adaptive and scalable in order to provide professional development-related exercises, and can be used in hospitals for rehabilitation following a surgery.

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Review of Theories and Studies on the Characteristics of Safety Culture

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KEYWORDS

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ABSTRACT

The concept of "safety culture" is notoriously nebulous! Over the last 30 years, researchers have proposed a wide range of definitions, ranging from simple ones, such as "the way we improve operations without sacrificing worker safety," to complex ones, such as "what people at all levels of an organization do and say when their commitment to safety is not being scrutinized." A robust safety culture is commonly seen as a prerequisite for a well-functioning safety management system; this implies that one cannot have an effective safety management system (policies, procedures, formal plans, dealing with risk and safety-related information) without a safety culture (shared values, beliefs, and attitudes regarding safety, etc.). Across all industries, cultivating a positive safety culture is becoming a major responsibility. This paper looks at what it takes to have a good safety culture and why it is so important.

1. INTRODUCTION

According to the International Labour Organization (ILO), approximately 2.3 million women and men die each year as a result of work-related accidents or diseases; this equates to over 6,000 deaths per day. Every year, there are approximately 340 million occupational accidents and 160 million victims of work-related diseases worldwide. The ILO updates these estimates at regular intervals, and the updates show an increase in accidents and diseases. Over 11,000 fatal occupational accidents are estimated to have occurred in the Commonwealth of Independent States (CIS) countries, compared to 5,850 reported cases (information lacking from 2 countries). Gross underreporting of work-related accidents, diseases and deaths, gives a false picture of how big the problem is.

Below are some of the most important things that the ILO's most recent statistics on accidents, diseases and deaths at work around the world have shown:

- Work-related diseases are the leading cause of death among workers. Every year, hazardous substances are estimated to kill 651,279 people.
- Accidents in the construction industry are disproportionately common.

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- Workers, both young and old, are particularly vulnerable. Because developed countries' populations are aging, an increasing number of older people are working and require special consideration.

Since 1996, the ILO has designated April 28 as World Day for Safety and Health at Work, a day to focus the attention of the world's governments, workers, and employers on a common agenda centered on reducing suffering through preventative measures. The ability to address the causes and stop the suffering is the unifying theme. Fortunately, an increasing number of companies are proving that safer, healthier workplaces can be created via collaboration and communication between employees, employers, and governments. This is the new trend of encouraging a "safety culture" at work.

According to the ILO, a safe culture necessitates three essential commitments:

- A commitment from businesses to implement occupational health and safety management systems.
- A commitment to worker participation and involvement in such systems.
- A commitment to create a global framework so that local action on safety and health is not undermined by erroneous competitiveness concerns.

These pledges are based on the ILO's real-world experience working with its tripartite partners – governments, workers, and employers – to solve the most pressing challenges pertaining to workplace safety and health. It is evident that businesses with an occupational safety and health system developed in accordance with ILO recommendations perform better in terms of both safety and productivity. Modern managers are aware that worker input is a valuable resource for enhancing workplace safety, productivity, and competitiveness. Historical evidence demonstrates that strong and effective union representation results in safer workplaces. In Sweden, for example, high safety standards are a direct result of worker participation laws and practices that have been in place for a long period of time and a tripartite system that works well.

This paper examines what creating a positive safety culture entails and why it is so vital. It provides an exemplary literature review. What is meant by an exemplary literature review? A literature review can be divided into two categories: exemplary and exhaustive. It has been noted that "in the exemplary review, the writer assumes the reader knows about the subject and so presents only key references to reacquaint the reader with representative works that relate to the research study". On the other hand, an exhaustive literature review is thought to be complete because the author looks up and presents all of the information about the research area (Rubin et al., 2009, p.236).

2. LITERATURE REVIEW

The purpose of the literature review was to examine the scientific literature pertaining to the value of safety and safety as a value. Safety can be an asset for organizations, individuals (such as managers and employees), and society as a whole. Other than economic worth, there are very few peer-reviewed scientific articles on the value of safety. In fact, the value of safety and safety values are implicit in the majority of safety research (as the objective is often to contribute in some way to the enhancement of safety). However, it is rarely directly addressed in scholarly publications (Ratilainen R., 2016).

Internationally, the importance of safety and safety values is gaining prominence. The International Atomic Energy Agency (IAEA, 2009) was perhaps the first international body to declare that "safety should be a clearly an acknowledged value." "Safety as a fundamental value" is a requirement of the most recent European Guidelines for offshore operations of the oil and gas industry.

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The phrase "safety is our value" is also frequently utilized by industry leaders and consultants (Ratilainen R., 2016). Many businesses state that safety is their top priority, but does this imply that safety is a (fundamental) value? Values are the guiding concepts or principles that govern an organization's internal behavior and its interactions with the outside world. People are guided by their values as to what is good or desirable and what is not. This shows that values are more stable and likely to have a longer-lasting effect on safety than "priorities."

Many businesses nowadays have articulated their basic principles; these serve to define and cultivate their "business identity." In the management literature, the influence of shared core values is frequently discussed. According to McKinsey's well-known 7S framework, shared values influence an organization's structure, strategy, systems, style, skills, and personnel.

In recent years, safety research has increasingly accepted that (value-based) management commitment and an economic viewpoint are vital for safety performance. However, little research has been conducted on the value of safety; there is confusion on the definition and impact of safety values, and there are no evidence-based techniques to support, promote, and disseminate safety values.

One can assert that safety has an intrinsic value (Zwetsloot G. et al., 2013). There are many grounds to believe that workplace safety has inherent value. Certainly, "what the majority of people consider to be vital in life" includes safety (a definition of value). However, this does not provide us with a definition of the value of safety or safety values.

There are various interpretations of the concept of safety culture in the literature, with perhaps the most significant difference being between authors who see safety culture as something that an organization has or does not have, and others who see safety culture as the intersection of the organization's culture (something that all organizations develop over time) and safety culture. In this latter interpretation, it is important to note that organizational culture may serve as a reservoir of tacit knowledge on safe ways of working, act as a soft coordination mechanism, and encourage people to maintain a questioning attitude, challenging beliefs and practices, and increasing imagination about possible accident scenarios. It may also shield members of an organization from opposing views, penalize deviation from group norms, and perpetuate myths that foster the illusion of control (Clarke, 1993). Several papers on safety culture have been published in the World Safety Journal, such as: Lal H., 2022; Lal H., 2021; Baylee S., Brazilie B. & Gilkey D., 2020; Marais W. & Jansz J., 2019a; Marais W. & Jansz J., 2019b; Gilkey D. & Lopez C., 2018; Yu S., 2018; Cervantes M., 2017; Bo W., 2017; Chiri K. & Jansz J., 2016; and Yu S., 2016).

One complete definition of safety culture comes from the HSC's Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993).

> *'The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety culture are characterised by communication founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.'*

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According to Marsden (2021), a "safety culture" is an organizational culture that provides safety concepts, values and attitudes, a high level of importance that is shared by most employees or workers. Organizational culture can be thought of as consisting of three interrelated levels, as shown in Figure 1 below (Schein, 1985). As Figure 1 reveals, the "deepest" level of an organization's culture is made up of its fundamental assumptions and beliefs: what people value; what contributes to performance; what performance means; and the stories members tell newcomers to the organization. These are intangible, tacit (not written or verbalized), and unspoken attitudes and beliefs. The second level consists of values, shared principles, rituals, behavioral standards, and goals. It also includes public statements about the organization's values and rules of conduct (how the members represent the organization to themselves and to others). Lastly, the "surface" level includes artifacts, the physical environment, interaction mechanisms, official policies, the dress code, and other visible parts of how people in the organization interact with each other (Schein, 1985).

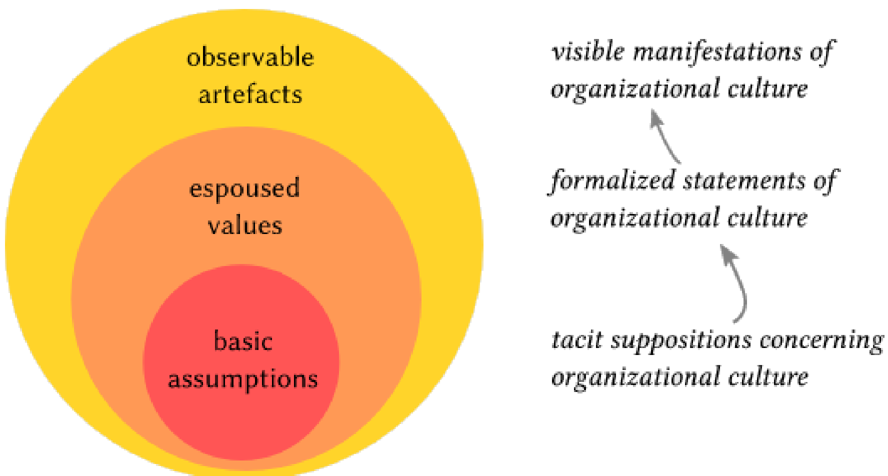

Figure 1. Schein's "onion layer" model of organizational culture (Schein, 1985)

Organizational culture is something that an organization is not something that can be changed quickly or easily (gothamCulture). Subcultures that differ from the dominant organizational culture are commonly found in large organizations. Subcultures form within organizations when members with similar identities or job functions band together to form their own interpretations of the organizational culture. Edgar Schein, an organizational theorist, identified three subcultures that exist in many organizations: executives, whose primary concern is financial performance; engineers, who solve problems using technology and specialized knowledge; and operators, who run the organization's systems. Within complex organizations, there are frequently much narrower subcultures based on age, occupation, seniority, shift, and previous occupation (Mearns et al., 1998).

3. SAFETY CULTURE DIMENSIONS

According to Reason (1990), safety culture has several dimensions, which are depicted in Figure 2 below.

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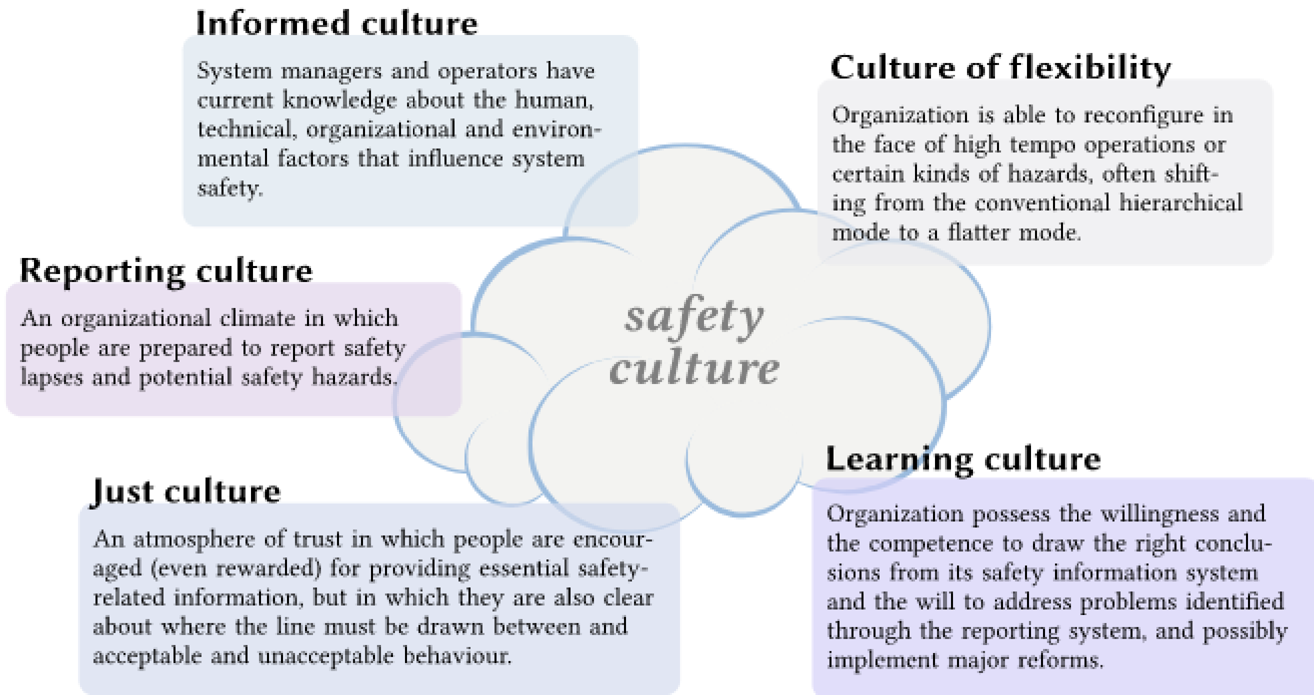

Figure 2. Dimensions of safety culture (Reason, 1990)

Turner (1992) identified four dimensions of a "good" safety culture:

- the development of a compassionate organizational response to the consequences of actions and policies.
- a commitment at all levels, particularly the most senior, as well as an avoidance of overly stringent safety attitudes.
- feedback to practitioners from incidents within the system.
- the development of comprehensive and widely accepted rules and norms for dealing with safety issues, supported in a flexible and non-punitive manner.

According to Pidgeon and O'Leary (2000), a "good" safety culture may reflect and be promoted by four dimensions:

- senior management's commitment to safety.
- realistic and adaptable practices and customs for dealing with both well-defined and ill-defined hazards.
- continuous organizational learning through practices such as operational experience feedback.
- concern for hazards are shared throughout the workforce.

These attempts to break down the idea of safety culture into a small number of easy-to-understand (and maybe even measure) dimensions are appealing, but it should be noted that there is not much evidence that these dimensions cover the same things as Reason's (1990) broader concept.

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4. ASSESSMENT OF SAFETY CULTURE

Safety culture can be "assessed" (defined along several dimensions) using a variety of methods, including questionnaires, interviews, focus groups, and observations (Eeckelaert et al. 2011). In the real world, quantitative questionnaires are the easiest and least expensive way to evaluate people; they are also the most popular method used in business.

There are numerous questionnaires available on the market. They cover the following dimensions:

- Priority, commitment, and competence in management safety.
- Management empowerment for safety.
- Justice for management safety.
- Workers' dedication to safety.
- Workers' safety and risk rejection.
- Communication about safety, learning about safety, and trust in coworkers' safety competence.
- Belief in the effectiveness of safety systems.

It should be noted that assessments based on surveys are prone to severe biases. When filling out surveys, people often give answers that they believe to be socially desirable rather than those that accurately reflect their true beliefs or attitudes. Worries about repercussions ("would our unit be punished if our results were bad?") for poor survey performance can also discourage participation in safety culture surveys. In addition, people are sensitive to the prevailing social atmosphere. Also, when morale is low, survey limitations become clearer because people are less likely to say what they really think about the company's culture out of fear of getting in trouble.

5. ORGANIZATIONAL FACTORS THAT INFLUENCE THE HEALTH AND SAFETY CULTURE

A number of organizational factors have been found to influence the health and safety culture of an organization and are also associated with good safety performance. According to the ILO, the key ones are:

- Effective communication requires a high level of communication between and within organizational levels, as well as comprehensive formal and informal communications.
- The learning organization must constantly improve its methods and learn from its errors.
- A strong focus on health and safety by everyone in the organization on health and safety is a must.
- Pressures from outside the organization, such as the organization's financial status and the impact of regulatory bodies, must be taken seriously.
- Time, money, and personnel devoted to health and safety are strong indicators of dedication.
- Employees at all levels of the organization must identify hazards, propose control measures, provide feedback, and establish safety procedures.
- Senior executives must demonstrate a strong commitment to safety.
- The need for productivity must be properly balanced with the need for health and safety, so that the latter are not overlooked.
- High-quality training must be well managed, with well-chosen content and high quality. Counting the hours spent on training is insufficient.
- A clean and comfortable work environment is required, including general cleanliness, plant layout, etc.

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- Safety, trust, and recognition of the impact of good safety performance, must be regarded.
- The composition of the labor force must be taken into account. For instance, studies have shown that a significant proportion of older, more experienced, and socially stable workers have fewer accidents, lower absenteeism, and lower turnover.

The HSE has suggested that the following components be included in an organization's management system (Health & Safety, 2022):

- Top-down commitment to creating a safe environment in which management's goals and the need for appropriate standards are openly discussed, and the free flow of information is actively supported at all levels.
- Incident investigation and making good use of data gathered from those probes must be implemented to achieve this goal. Furthermore, adequate and effective supervision is required to address deficiencies as they arise.

6. ORGANIZATIONAL FACTORS ASSOCIATED WITH A CULTURE OF SAFETY AND HEALTH

The foundation of good health and a safety culture is an effective health and safety management system. Certain key aspects of an organization's culture influence it. According to the ILO, these factors are often intangible and difficult to change or incorporate:

- The commitment of senior management is critical for fostering a positive health and safety culture. This commitment instills a sense of urgency and concern for health and safety throughout the organization. The proportion of resources (time, money, and people) and support dedicated to health and safety management, as well as the status accorded to health and safety, best demonstrate this. Senior management's active participation in the health and safety system is critical. Managers must lead by example in terms of health and safety.

- Effective management style. A 'humanistic' management approach in which managers pay more attention to individuals' personal and professional problems is likely to be effective. This requires prompt and direct action to identify and resolve individual problems in a caring and concerned manner.

- Visible management is essential for fostering a health and safety culture. Good managers must visit the "shop floor" frequently to discuss health and safety. Employees must have confidence that all of their managers care about their health and safety.

- Effective communication at all organizational levels. An "open door" policy with direct access to the management hierarchy may be advantageous where appropriate. In a positive culture, questions about health and safety should be part of everyday work conversations. This stems from ownership, which encourages everyone to look after themselves and contribute to health and safety measures.

- A balance of health, safety, and productivity goals. People may mistakenly believe that high health and safety standards necessitate slower work rates. In contrast, production may appear to be increased by 'cutting corners.' Excessive production pressure creates a distraction-filled environment with a lack of time, which increases the likelihood of human error. Excessive pressure can lead to physical or mental health issues in some employees, as well as an increase

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> in 'violations' of health and safety regulations. Health and safety are valued, promoted, and not jeopardized in a positive culture.

To help alleviate organizational issues that are associated with a culture of safety and health, the Health and Safety Commission (HSC) issued recommendations for board members to follow (Health & Safety, 2022). According to HSC, each board member individually and the Board as a whole are responsible for setting a tone of leadership in terms of health and safety. If the Board is serious about improving health and safety, it must make that aim clear in all of its actions and involve employees in those efforts. In addition, the Board must remain abreast of developing health and safety concerns. Further, the Board's efforts to improve health and safety will be viewed as clear indicators of their commitment.

7. THE TOP 10 SAFETY CULTURE CONCERNS

7.1 What does safety culture entail?

All of the attitudes, practices, and beliefs about safety that exist in any establishment are referred to as the "safety culture". The atmosphere created by those attitudes, beliefs, etc., can be defined as the company's culture.

Safety culture affects how employees act and is caused by a number of things, such as:

- Employee and management norms, beliefs, and assumptions;
- Employee and management attitudes;
- Values, myths, and stories;
- Policies and procedures;
- Responsibilities, priorities, and accountability of supervisors;
- Inaction or actions taken to correct risky behavior;
- Bottom-line and production demands vs. quality concerns;
- Employee involvement, or "buy in"; and
- Motivation and employee training.

7.2 Are employees at ease asking questions about safety?

If employees are hesitant to ask safety-related questions or are afraid of being disciplined for raising safety concerns, it is very likely that someone will be injured by one of those uncorrected hazards.

The most effective organizations have open lines of communication, and management is always willing to address safety concerns.

7.3 Are employees from one trade comfortable approaching someone from another trade in an emergency?

Simply put, no one enjoys being questioned, especially by someone from a different trade. "Who are you to tell me how to do my job properly?" is the most common response.

However, in the most positive environment, employees from various departments feel free to offer advice to those from other departments in order to prevent injuries.

7.4 Is it mandatory for employees to report close calls and incidents?

Employees in environments with a healthy safety culture are always looking for new ways to improve safety, which necessitates learning from close calls. If these incidents are dismissed or ignored, there is a much lower chance that a more tragic event will occur in the future.

One of the most important questions about safety culture is whether or not your employees are encouraged to report close calls and incidents.

7.5 How are hazardous conditions addressed?

It is critical that all reports of unsafe conditions be corrected as soon as possible. If not, it communicates to employees that their safety is not valued.

When hazards are promptly corrected, employees feel valued and are more likely to report similar incidents in the future.

7.6 Can your employees refuse to work in potentially hazardous conditions?

The safest workplaces are those in which management trusts employees enough to make decisions about their own safety.

Simply put, if a worker considers an area unsafe to work in, they should not be required to do so. It conveys the organization's trust and respect for each employee.

7.7 How involved are managers in the safety process?

Supervisors should discuss safety at every meeting and walk around the site to identify problems as soon as possible. Simply put, managers should not only talk the talk, but also walk the walk.

It will be even more difficult to persuade workers of the importance of safety if it is not discussed on every walk-around and at every meeting. Supervisors must set a good example.

7.8 Is the company offering any incentives to discourage incident reporting?

While everyone loves incentives, programs that discourage employees from reporting any type of safety incident can completely undermine the safety culture.

Because no employee wants to be blamed for not receiving an incentive, it is critical to carefully craft programs. They must be designed in such a way that they do not discourage incident reporting.

7.9 Are employees stressed and prone to taking shortcuts?

Most projects are under severe budget and time constraints, which may lead to employees seeking shortcuts. Better planning that includes safety provisions is one way to alleviate these pressures.

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7.10 Is the management team attentive?

Supervisors must be active listeners as well as active participants in all safety programs. They must actively consider suggestions for improvement and never dismiss them.

Most of the time, employees will have the best ideas because they are on the ground and are likely to know where the problems are.

8. THE ROLE OF SAFETY CULTURE: AN INTERVIEW WITH AN HSE EXECUTIVE

Prior to the MENA HSE Forum, which was held in Dubai on September 6-7, 2022, the head of HSE at Kuwait Energy Egypt, Wael Amin, emphasized the significance of developing an effective safety culture (HSSR, 2022). Below are the interview's Q&A.

Q. What is safety culture?

A. Modern conceptions of safety culture vary widely. The majority of them are based on the definition provided by the Advisory Committee on Safety from the 1980s, which states that it is "the product of individual and group values, attitudes, competencies, perceptions, and behavioral patterns that determine the commitment to, and the style and proficiency of an organization's health and safety management."

OSHA defines safety culture as "shared beliefs, practices, and attitudes that exist at a workplace." Culture is the environment created by the beliefs, attitudes, and so on that shape our behavior. The following are some of the advantages of a strong safety culture:

- Creating a strong safety culture has the greatest single impact on accident reduction of any process.
- A company with a strong safety culture has fewer risky behaviors, lower accident rates, lower turnover, lower absenteeism, and higher productivity.
- Building a stronger safety culture benefits not only safety, but also productivity, staff retention, and the overall organizational culture.
- It is critical to understand that effective consequences for behaviors and performance are required for successful world-class safety cultures.

Q. How crucial is it to establish a successful safety culture?

A. In order to understand the significance of a safety culture in the workplace, we should first notice the following: According to the International Labor Organization (ILO), workplace accidents and illnesses account for 2.3 million deaths worldwide each year. That translates to 13 fatalities per 100,000 workers globally. The rate ranges from 0.5 to 3.5 deaths per 100,000 workers in wealthy nations, but it climbs rapidly to about 19 deaths per 100,000 workers in rising economies like sub-Saharan Africa, Latin America, and southern Asia. In addition to the human tragedy, workplace accidents cost the economy roughly 4% of GDP. Before the Health and Safety at Work Act was implemented in the UK in 1974, there were typically 650 fatal workplace accidents per year. By 2016/2017, there were 137 fewer fatalities, or less than one-fourth of that number.

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High standards are set for all safety procedures thanks to a strong safety culture. The organization has tight procedures for reporting, inspecting, training, and general safety management. A "safety culture" is an organizational culture that gives safety concepts, values, and attitudes a high level of importance and that is shared by most employees or workers. You could say it is "the way we do things around here."

Q. What steps would you take to create a strong safety culture, and what conditions must be met for success?

- Make safety a core value, not just a top concern. The guiding principles should be a part of everyday life.
- Strong management commitment entails fast and attentive engagement in all layers (layered safety interactions), making the safety management system (SMS) more than just a formal procedure to prove legal compliance. At every level of business, people work together to achieve the same production-related goals and ideals.
- Empowering people to successfully meet their safety responsibilities to their families, coworkers, and themselves.
- Communication: Make sure there is top-down and bottom-up feedback and two-way communication.
- Ongoing improvement: Have we improved since yesterday?

Q. What are the biggest obstacles to establishing and preserving a strong safety culture?

- Safety is viewed as more of a barrier than a value, and profit is the major priority.
- Autocratic and oppressive management.
- A culture of punishment has resulted in a lack of trust.
- Insufficient reporting, with few events, concerns, or near-misses reported.
- Ineffective work monitoring and evaluation; failure to employ performance indicators, audit results, and incident reporting for study of safety management system's efficacy and organizational learning.
- The inability of managers at all levels to effectively manage risk.

Q. How do safety culture and the safety management system relate to one another?

A. A well-functioning safety management system is typically thought to require a strong safety culture. This indicates that without a safety culture (common values, beliefs, and attitudes about safety, etc.) in place, it is impossible to create an effective safety management system (policies, procedures, formal plans, dealing with risk and safety-related information).

9. CONCLUSION

Clearly, the influence of organizational cultural features on safety performance is an important area of research. Unfortunately, rather than seeking to appreciate current studies on organizational culture, a great deal of attention has been paid to a different set of theorized traits known as the "safety culture". Creating and sustaining a healthy safety culture is a significant and complex task. Safety must be ingrained in every individual, regardless of rank, for a successful safety culture to exist.

Several safety-related values are essential for promoting or establishing safety practices and/or a safety culture. Justice (Dekker, 2007; Reason, 1997), trust, and knowledge (Reason, 1997) are the most well-known. Trust between managers and employees, and a just culture appear to be prerequisites for the propagation of safety values.

The relationship between safety values and company culture is close. However, safety culture is a broader notion (with multiple meanings) that encompasses values, norms, attitudes, practices, and principles connected to safety.

A strong safety culture ensures that all safety processes comply with stringent regulations. Commonly, a strong safety culture is seen as a necessity for an effective safety management system. This means that a safety culture (shared values, beliefs, and attitudes about safety, etc.) is needed for a safety management system (policies, procedures, and formal plans that deal with risk and safety-related information) to work.

According to the literature review, any safety program or culture depends on a strong safety leadership. There is nothing directing the program to success without solid leadership. Every leader must follow these seven guidelines in order to "walk the walk" when it comes to safety:

- **Vision**. In order to communicate safety excellence throughout the business, leaders must be able to "see" what it looks like.
- **Collaboration**. Effective leaders have good interpersonal skills, foster teamwork and collaboration, aggressively seek out the opinions of others on matters that concern them, and motivate their followers to carry out their decisions to increase safety.
- **Credibility**. Do the followers of the leader exhibit a great degree of trust? This means that everyone, from management to front-line workers, needs to be willing to take responsibility for mistakes and promote safety.
- **Communication**. Every time a safety leader speaks, they need to address safety. They must always speak from the perspective of safety.
- **A focus on action**. Is the safety leader prepared to take a proactive approach to safety rather than merely responding to incidents? Even in the absence of events, safety leaders need to act with haste to demonstrate their commitment to getting results.
- **Feedback and acclaim**. To help them assure consistency between their love for people and the message employees perceive based on their actions, leaders require honest and accurate feedback on the impact of their behaviors.
- **Accountability**. Any good leader promotes the idea that everyone in the organization is responsible for keeping things safe by giving workers an honest assessment of their safety efforts and results.

All of these factors come together to produce a culture that is both exemplary in terms of safety and conducive to workers wanting to do their jobs safely. In this endeavor, leaders in top-tier safety organizations can act as role models. Everything begins with a personal commitment to putting employees first, not last.

In conclusion, an organization's health and safety culture is an important factor in achieving and maintaining good health and safety performance. Open communication, management's commitment and leadership, the availability of resources, and balancing production goals with health and safety goals are all important parts of creating a positive culture.

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World Safety Organization (WSO)

The WSO was founded in 1975 in Manila, The Republic of the Philippines, as a result of a gathering of over 1,000 representatives of safety professionals from all continents at the First World Safety and Accident Prevention Congress. The WSO World Management Center was established in the United States of America in 1985 to be responsible for all WSO activities, the liaison with the United Nations, the co-operation with numerous Safety Councils, professional safety/environmental (and allied areas) organizations, WSO International Chapters/Offices, Member Corporations, companies, groups, societies, etc. The WSO is a non-profit, non-sectarian, non-political organization dedicated to: ***"Making Safety a Way of Life … Worldwide."***

World Safety Organization Activities

WSO publishes WSO Newsletters, World Safety Journal, and WSO Conference Proceedings.

WSO provides a network program linking various areas of professional expertise needed in today's international community.

WSO develops and accredits educational programs essential to national and international safety and establishes centers to support these programs.

WSO receives proposals from professional safety groups/ societies for review and, if applicable, submits them to the United Nations for adoption.

WSO presents annual awards: The James K. Williams Award, Glenn E. Hudson International Award, J. Peter Cunliffe Transportation Award, Concerned Citizen, Concerned Company/Corporation, Concerned Organization, Educational Award, WSO Chapter/National Office of the Year, and Award for Achievement in Scientific Research and Development.

WSO provides recognition for safety publications, films, videos, and other training and media materials that meet the WSO required educational standards.

WSO establishes and supports divisions and committees to assist members in maintaining and updating their professional qualifications and expertise.

WSO has Chapters and National/International Offices located throughout the world, providing contact with local communities, educational institutions, and industrial entities.

WSO organizes and provides professional support for inter- national and national groups of experts on all continents who are available to provide expertise and immediate help in times of emergencies.

Benefits of Membership

WSO publishes the "WSO Consultants Directory" as a service to its Members and to the Professional Community. Only Certified Members may be listed.

WSO collects data on the professional skills, expertise, and experience of its Members in the WSO Expertise Bank for a reference when a request is received for professional expertise, skill, or experience.

WSO provides a network system to its Members whereby professional assistance may be requested by an individual, organization, state, or country or a personal basis. Members needing assistance may write to the WSO with a specific request, and the WSO, through its Membership and other professional resources, will try to link the requester with a person, organization, or other resource which may be of assistance.

WSO provides all Members with a Membership Certificate for display on their office wall and with a WSO Membership Identification Card. The WSO awards a Certificate of Honorary Membership to the corporations, companies, and other entities paying the WSO Membership and/or WSO Certification fees for their employees.

Members have access to WSO Newsletters and other member- ship publications of the WSO on the WSO website, and may request hard copies by contacting the WSO World Management Center. Subscription fees apply to certain publications.

Members are entitled to reduced fees at seminars, conferences, and classes given by the WSO. This includes local, regional, and international programs. When Continuing Education Units (CEUs) are applicable, an appropriate certificate is issued.

Members who attend conferences, seminars, and classes receive a Certificate of Attendance from the WSO. For individuals attending courses sponsored by the WSO, a Certificate of Completion is issued upon completion of each course.

Members receive special hotel rates when attending safety pro- grams, conferences, etc., sponsored by the WSO.

Membership

The World Safety Organization has members who are full time professionals, executives, directors, etc., working in the safety and accident prevention fields, including university professors, private consultants, expert witnesses, researchers, safety managers, directors of training, etc. They are employees of multinational corporations, local industries, private enterprises, governments, and educational institutions. Membership in the World Safety Organization is open to all individuals and entities involved in the safety and accident prevention field, regardless of race, color, creed, ideology, religion, social status, sex, or political beliefs.

Membership Categories

Associate Membership: Individuals connected with safety and accident prevention in their work or individuals interested in the safety field, including students, interested citizens, etc. **Affiliate Membership**: Safety, hazard, risk, loss, and accident prevention practitioners working as full time practitioners in the safety field. Only Affiliate Members are eligible for the WSO Certification and Registration Programs. **Institutional Membership**: Organizations, corporations, agencies, and other entities directly or indirectly involved in safety activities and other related fields. **Sustaining/Corporate Member**: Individuals, companies, corporations, organizations or other entities and selected groups, interested in the international effort to "Make Safety A Way of Life ... Worldwide."

The WSO Membership Application is included on the following pages and is also available on the WSO website: https://worldsafety.org/quick- downloads/

WSO – Application for Membership

[✓] Application Fee $20.00 USD
[ ] Associate Membership $65.00 USD
[ ] Affiliate Membership $90.00 USD
[ ] Institutional Membership*) $195.00 USD
[ ] Corporate Membership*) $1000.00 USD

*) In case of institution, agency, corporation, etc., please indicate name, title, and mailing address of the authorized representative.

(Please print or type.)

NAME (Last, First, Middle) [ ] Mr. [ ] Ms. [ ] Mrs. [ ] Dr. [ ] Engr.
BIRTHDATE:
POSITION/TITLE:
COMPANY NAME AND ADDRESS: [ ] Preferred
HOME ADDRESS: [ ] Preferred
BUSINESS PHONE: / FAX:
CELL PHONE: / HOME PHONE:
E-MAIL ADDRESS(ES):
PROFESSIONAL MEMBERSHIP(S), DESIGNATION(S), LICENSE(S):
EDUCATION (degree(s) held):

REFERRAL

If you were referred by someone, please list his/her name(s), chapter, division, etc.:

WSO Member: ____

WSO Chapter: ____

WSO Division/Committee: ____

Other: ____

PLEASE specify your area of professional expertise. This information will be entered into the WSO "Bank of Professional Skills," which serves as a pool of information when a request for a consultant/information/expertise in a specific area of the profession is requested.

[ ] Occupational Safety and Health (OS&H)
[ ] Environmental Safety and Health (EH&S)
[ ] Fire Safety/Science (FS&S)
[ ] Safety/Loss Control Science (S&LC)
[ ] Public Safety/Health (PS&H)
[ ] Construction Safety (CS)
[ ] Transportation Safety (TS)
[ ] Industrial Hygiene (IH)
[ ] Product Safety (PRO)
[ ] Risk Management (RM)
[ ] Hazardous (Toxic) Materials Management (HAZ)
[ ] Nuclear Safety (NS)
[ ] Aviation Safety (AS)
[ ] Ergonomics (ERG)
[ ] Petroleum (PS)
[ ] Oil Wells (OW)
[ ] Other: ____

PAYMENT OPTIONS

For secure Credit Card Payment, please visit the SHOP on WSO's website (https://worldsafety.org/shop) and select "WSO Membership Application Fee" to make your payment. You will receive an emailed invoice for the Membership Fee upon approval.

Check or Money Order payable to WSO may be mailed with application packet to: WSO-WMC, Attn: Membership Coordinator, PO Box 518, Warrensburg MO 64093 USA. International postal money orders or bank drafts with a U.S. routing number are acceptable for applicants outside the United States. For alternate payment arrangements, please contact WSO-WMC.

Annual dues hereafter will be billed and payable on the anniversary date of your membership. **U.S. funds only.**

By submitting this application, you are accepting that WSO will use the information provided to perform an independent verification of employer, credentials, etc.

Mail or email completed form, along with current résumé/CV:

WSO World Management Center
PO Box 518 | Warrensburg, Missouri 64093 USA
Phone 660-747-3132 | FAX 660-747-2647 | membership@worldsafety.org

Student Membership Application

WORLD SAFETY ORGANIZATION

Instructions | Complete all applicable fields and mail to **WSO World Management Center, PO Box 518, Warrensburg, MO 64093 USA**, email to **membership@worldsafety.org**, or fax to **1-660-747-2647**. For assistance completing this application, please call **1-660-747-3132**, or email questions to **membership@worldsafety.org**.

Membership Level | Choose One

❑ **College/University Student Membership – FREE**

*You will receive all member benefits including subscriptions to **WSO World Safety Journal** and **WSO NewsLetter**, as well as access to **WSO's Mentor Program**.*

❑ **Middle/High School Student Membership – FREE**

*You will receive all member benefits including subscription to **WSO World Safety Journal** and **WSO NewsLetter**, excluding access to **WSO's Mentor Program**.*

Last Name/Family Name

First Name/Given Name ____ Initial ____ ❑ M ❑ F (Gender)

Birthdate MM / DD / YYYY *(Application must include exact birthdate with year to be processed.)*

Current Street Address ❑ On Campus ❑ Off Campus *(Attach separate sheet if you need more room for your address.)*

City ____ State/Province ____ Country

Zip/Postal Code ____ Telephone Number (including area code) ____ ❑ Landline ❑ Mobile (Type)

Permanent Street Address

City ____ State/Province ____ Country

Zip/Postal Code ____ Telephone Number (including area code) ____ ❑ Landline ❑ Mobile (Type)

Send mail to: ❑ Current Address ❑ Permanent Address

Email Address(es)

COLLEGE/UNIVERSITY STUDENT

Category: ❑ Undergraduate ❑ Graduate/Post-Graduate

Degree(s) Sought/Obtained

Name of College/University ____ Campus

MIDDLE / HIGH SCHOOL STUDENT

❑ I am a Middle Schooler in: ❑ 6th Grade ❑ 7th Grade ❑ 8th Grade

❑ I am a High School: ❑ Freshman ❑ Sophomore ❑ Junior ❑ Senior

Name of School

Approximate Date of Graduation (MM / YYYY)

(For High School and College/University students, application must include approximate date of graduation to be processed.)

If you were referred by someone, please list name(s), chapter, division, etc.:

WSO Member: ____

WSO Chapter/National Office: ____

WSO Division/Committee: ____

Other: ____

What Interests You?

Please specify your area(s) of interest. These areas of interest will allow you to connect with others who share similar interests throughout the world.

[ ] Occupational Safety and Health (OS&H)
[ ] Environmental Safety and Health (EH&S)
[ ] Fire Safety/Science (FS&S)
[ ] Safety/Loss Control Science (S&LC)
[ ] Public Safety/Health (PS&H)
[ ] Construction Safety (CS)
[ ] Transportation Safety (TS)
[ ] Industrial Hygiene (IH)
[ ] Product Safety (PRO)
[ ] Risk Management (RM)
[ ] Hazardous (Toxic) Materials Management (HAZ)
[ ] Nuclear Safety (NS)
[ ] Aviation Safety (AS)
[ ] Ergonomics (ERG)
[ ] Petroleum (PS)
[ ] Oil Wells (OW)
[ ] Other: ____

Required Signatures & Permissions

I subscribe to the above record and when approved will be governed by the Constitution and By-Laws of WSO and its Code of Ethics as I continue as a member. I furthermore agree to promote the objectives of the WSO wherever and whenever possible.

X ____ Applicant Signature ____ Date

FOR MID/HIGH SCHOOLERS ONY: WSO subscribes to the Family Educational Rights and Privacy Act (FERPA) philosophy in protecting student privacy and information. WSO may disclose "directory" information such as a student's name, WSO Student Chapter affiliation, name of school, grade in school, etc., along with group or individual photos in WSO NewsLetters, NewsFlashes, eNews, on WSO website, and on WSO's social media accounts.

❑ My student has permission to participate as outlined above.

❑ My student has permission to participate with exclusions:

X ____ Parent/Guardian Signature (Mid/High Student) ____ Date

X ____ WSO Student Chapter Mentor Signature ____ Date

[IF APPLICABALE]

File: Application_Student_2019; 03/2019

WSO – National Offices

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World Safety Organization
Code of Ethics

Members of the WSO,
by virtue of their acceptance of membership
into the WSO,
are bound to the following Code of Ethics
regarding their activities associated with the WSO:

Members must be responsible for ethical and professional conduct in relationships with clients, employers, associates, and the public.

Members must be responsible for professional competence in performance of all their professional activities.

Members must be responsible for the protection of professional interest, reputation, and good name of any deserving WSO member or member of other professional organization involved in safety or associate disciplines.

Members must be dedicated to professional development of new members in the safety profession and associated disciplines.

Members must be responsible for their complete sincerity in professional service to the world.

Members must be responsible for continuing improvement and development of professional competencies in safety and associated disciplines.

Members must be responsible for their professional efforts to support the WSO motto:

"Making Safety a Way of Life…Worldwide."

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