2022
ISSN 1015-5589, Vol. XXXI, No. 2

World Safety Journal

In This Edition

Effects of the covid-19 pandemic on employees' psychological health in the offshore oil and gas industry and opportunities for improvement
by Emma D'Antoine, Janis Jansz, Ahmed Barifcani, Sherrilyn Shaw-Mills, Mark Harris, and Christopher Lagat

From truck driver awareness to obstacle detection: A tiger never changes its stripes
by Todd Pascoe, Shirley McGough, and Janis Jansz

An analysis of investigation reports into heavy vehicle and train crashes in Australia suggests anomalies in investigations and reporting
by Ivan Cikara, Geoff Dell, Aldo Raineri, and Shevaun Dell

The economic cost of road traffic accidents in Lebanon
by Elias M. Choueiri, Elie Otayek, and Alain Saroufim

A platform management system that links commuters with shared or service taxis
by Rony Darazi, Elias M. Choueiri, Mira Bou Saleh, Elias Doumith, Anthony Tannoury, Abdulrahim Sekaki, and Amir Hajjam Al Hassani

WSO's Certification Program is accredited, in compliance with the ISO/IEC 17024:2012

World Safety Organization

Statement of Purpose and Objectives

WSO's purpose is to internationalize all safety fields, including occupational and environmental safety and health, accident prevention movement, etc., and to disseminate throughout the world the practices skills, arts, and technologies of safety and accident prevention.

WSO's objective is to protect people, property, resources, and the environment on local, regional, national, and international levels. WSO membership 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.

WSO is in Consultative Category II Status (Non-Governmental Organization - NGO) to the Economic and Social Council of the United Nations.

WSO is a Not-for-Profit Corporation (Missouri, USA), non-sectarian, non-political movement dedicated to:

"Making Safety a Way of Life … Worldwide."

Cover Photo

The PARAGON L1115 located some 100 km off the shore of Qatar.

Offshore oil and gas production, which involves extracting oil and gas from beneath the sea, is a critical component of the world's energy supply. It requires the use of increasingly sophisticated technology and ever greater attention to the related environmental impacts. Offshore production accounts for 30% of global oil production and 27% of global gas production. These percentages have remained stable since the early 2000s and are unlikely to change any time soon, despite the rapid onshore development of unconventional resources such as oil sands and shale oil and gas. Offshore production currently accounts for an estimated 20% of the world's oil reserves and 30% of global gas reserves. As with unconventional resources, the main constraints for offshore production concern cost and the environment. Despite technological advances, each stage of the oil and gas production process – from exploration, drilling and extraction to the construction of purpose-built platforms and vessels – requires billions of dollars in investment. Each project's cost competitiveness has to be assessed on a case-by-case basis.

Retrieved from:
https://www.planete-energies.com/en/medias/close/offshore-oil-and-gas-production/

Table of Contents

Effects of the covid-19 pandemic on employees' psychological health in the offshore oil and gas industry and opportunities for improvement
by Emma D'Antoine, Janis Jansz, Ahmed Barifcani, Sherrilyn Shaw-Mills, Mark Harris, and Christopher Lagat .... Pages 1-14

From truck driver awareness to obstacle detection: A tiger never changes its stripes
by Todd Pascoe, Shirley McGough, and Janis Jansz .... Pages 15-28

An analysis of investigation reports into heavy vehicle and train crashes in Australia suggests anomalies in investigations and reporting
by Ivan Cikara, Geoff Dell, Aldo Raineri, and Shevaun Dell .... Pages 29-46

The economic cost of road traffic accidents in Lebanon
by Elias M. Choueiri, Elie Otayek, and Alain Saroufim .... Pages 47-62

A platform management system that links commuters with shared or service taxis
by Rony Darazi, Elias M. Choueiri, Mira Bou Saleh, Elias Doumith, Anthony Tannoury, Abdulrahim Sekaki, and Amir Hajjam Al Hassani ......Pages 63-76

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.

References

Articles should be referenced according to the Publication Manual of the American Psychological Association ,7th ed.

Books are referenced as follows:
Author. (Year of publication). *Title of publication*. Publisher.

Articles are referenced as follows:
Author (Year). Title of article. *Name of Journal. Volume* (Issue), Page numbers of article.

Internet information is referenced as follows:
Name of author. (Year of publication). *Title*. DOI or web address if no DOI.

Submissions should be mailed to:

WSO, World Management Center
Attn: Editorial Staff /
Prof. Dr. Elias M. Choueiri
World Management Center, 106 W Young St #F
Warrensburg, MO 64093, USA
or emailed to: elias.choueiri@gmail.com

Articles, wherever possible, must be up-to-date and relevant to the Safety Industry. ***All articles are Blind Peer Reviewed by at least two referees before being accepted for publication.***

Disclaimer

Opinions expressed by contributors in articles, or reproduced articles, are the individual opinions of such contributors or the authors and not necessarily those of the World Safety Organization. Reproduction of articles or abstracts contained in this journal is approved, providing the source is acknowledged.

World Safety Journal

A peer-reviewed journal,
published by the World Safety Organization

Journal Homepage:
https://worldsafety.org/wso-world-safety-journal/

Effects of the COVID-19 pandemic on employees' psychological health in the offshore oil and gas industry and opportunities for improvement

Emma D'Antoine[1,*], Janis Jansz[1,2], Ahmed Barifcani[1], Sherrilyn Shaw-Mills[2], Mark Harris[3], Christopher Lagat[1]

[1] *WA School of Mines: Minerals, Energy and Chemical Engineering. Curtin University, Bentley, Western Australia.*

[2] *Healthforce Group: High Wycombe, Western Australia.*

[3] *School of Economics, Finance and Property. Curtin University, Bentley, Western Australia.*

KEYWORDS

COVID-19
Mental health
Offshore oil and gas

ABSTRACT

This qualitative study aimed to identify psychosocial hazards in the highly-stressful environment of the Australian offshore oil and gas industry. The study utilised a focus group, which consisted of 6 participants from various offshore facilities, at varied organisational levels and 2 representatives of 2 oil and gas legislative organisations. NVivo analysis showed that the main psychosocial concerns were casualisation, the COVID-19 pandemic and its effects on rosters and job security, fear of re-injury and making mistakes. The findings can be used to help guide policy and develop risk control measures for legislative bodies and organisations to minimise psychosocial hazards.

1. INTRODUCTION

Australia's offshore oil and gas employees are a neglected field in terms of research, particularly when considering psychological hazards. While the Australian onshore fly-in-fly-out (FIFO) sector has seen an increase in interest regarding psychosocial stressors in recent years (Bowers et al 2018; Parker et al 2018), its offshore counterpart remains relatively overlooked. Considering that the onshore FIFO industry has witnessed a significant increase in suicides over the past ten years (Parker et al 2018), and are a cohort which are much less likely to seek help for psychological distress (Bowers et al 2018), this research is not only crucial, but also timely.

As identified by Parkes (1992), offshore working environments present many hazards for employees and organisations alike. The isolated environment, with added factors such as changeable climate, extreme temperatures, variable ocean conditions and excessive geographical distance, along with long absences from home and family, close working and sleeping arrangements and irregular or long work shifts pose unique threats to psychological wellbeing. These factors may be present along with usual work stressors such as job demands, lack of autonomy (Bergh et al., 2014), bullying and violence (Commission for Occupational Safety and Health, 2019), and low levels of supervisor or colleague support (Wyatt & Lane, 2017).

Corresponding author: emma.dantoine@postgrad.curtin.edu.au

https://doi.org/10.5281/zenodo.6790705

The ongoing COVID-19 pandemic has exacerbated these existing psychosocial stressors for offshore oil and gas workers. New work rosters introduced to comply with COVID isolation procedures have seen an increase in poor mental health for FIFO employees in addition to having negative impacts on home and family life (Neis et al., 2020).

2. METHODOLOGY

This research was conducted as an exploratory study with the responses to the interview questions analysed qualitatively using NVivo to identify emerging themes. It was conducted to assist in formulating qualitative research questions for a larger study and was conducted in Perth, Western Australia. Participants were recruited according to an eligibility standard in order to obtain individuals who held specialist knowledge and understanding about the phenomena (Creswell, 2012), as well as being able to provide the researcher with insights from lived experience (van Manen, 1990). Approval was gained by the Human Research Ethics Committee (HREC) (Ethics Approval number HRE2021-0512).

The study used a focus group to provide insights into the psychosocial stressors present on offshore oil and gas facilities in Western Australia. Focus groups allow researchers to hear the experiences of several speakers at one time (Smith et al., 2009) and is a sufficient enough method of analysis to be used alone (Flick, 2007). As a diverse and varied group is required to satisfy the quality criteria for qualitative research, the focus group remained the ideal method for this study (Flick, 2007).

The focus group meeting was conducted online via Microsoft Teams and consisted of eight participants, making sure to be around the approximate number of participants suggested by several researchers. A minimum of six participants is recommended by Morse (1994). Creswell (1998) suggests between five to twenty-five participants, however the validity of a study in practical settings is increased with a sample size of less than twenty, which may also help develop the relationship between the researcher and the participant (Crouch & McKenzie, 2006). Moreover, the study can benefit from a richness and depth that a larger sample size may not generate (Smith & Osborn, 2008). The focus group was utilised to develop interview questions for a larger study and multiple sessions were not required as sufficient relevant information was obtained to develop the interview questions.

2.1 Participants

There were 8 participants in the focus group discussion. Representation of management in the offshore oil and gas industry was provided by participant #1, a Health, Safety, Security and Environment (HSSE) advisor who had ongoing employment at a large offshore oil and gas company. Participant #2 was an Offshore and Maintenance (O&M) crewing manager who managed the crewing for an offshore oil and gas contractor organization. Participant #3 was a representative from The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA), who had knowledge of offshore oil and gas legislation and Australian workplace health and safety. Participant # 4 was an offshore oil and gas contractor employee who worked on a casual basis, whilst participant # 5 was a graduate engineer with ongoing employment. Participant #6 was a representative of the Department of Mines, Industry Regulation and Safety (DMIRS), who gave insight into how onshore oil and gas mining organisations manage mental health concerns. Participant #7 was an offshore oil and gas contractor worker with ongoing employment for a contracting company. The contract workers were included with the intent of providing insights into the less permanent nature of this type of work. Participant #8 was a permanent employee of an offshore oil and gas service company. One participant was female and the remaining 7 participants were male.

https://doi.org/10.5281/zenodo.6790705

2.2 Procedure

The focus group meeting was conducted via Microsoft Teams, which, through the anonymous nature of the method, assisted in reducing individual inhibitions (Liamputtong, 2011), and in the facilitation of gathering unique personal insights along with common group experiences (Murray, 1997). Appendix 1 documents the focus group questions asked. Open-ended questions were used in this focus group, allowing members equal opportunities to contribute (Smith et al, 2009) and put forward detailed narratives of their experiences (Creswell, 2014), rather than a questionnaire, which would provide the researcher with a less holistic representation of the phenomena (Brannen, 2005). A semi-structured technique was utilised in order to draw out the most authentic and accurate accounts of participants' experiences. Questions were analysed separately, and word frequencies and word clouds were produced for each.

2.3 Analysis

During the focus group discussion, notes were taken by the researcher. After the focus group had concluded, the transcripts were read and reread with an open mind and transcripts were arranged into what each participant had said in response to each question. Transcripts were then returned to all participants for them to check and return to the researcher.

Using NVivo enabled the researcher to delve deeper into the data collected from the focus group and thus provided a rich account of participant experiences. NVivo is ideal for studies that use interpretative methods of analysis and for semi-structured interviews with a small sample size. NVivo assisted in the categorisation, classification and sorting of data in order to identify emerging themes. Due to the coding of data being the researcher's responsibility (Sotiriadou et al., 2014), it is then possible for the researcher to become more involved with the content. Codes and sub-codes were assigned to phrases in the discussion and patterns and themes were revealed in the content. The findings from the analysis were then compared with the results from the literature review.

2.4 Validity, reliability, credibility and generalisability

Participants' transcripts were returned to them for checking, ensuring their accuracy and validity, as well as representing participants' experiences (Birt et al., 2016; Long & Johnson, 2000). Member checking also adds to the study's credibility (Ramsook, 2018). Participants made any necessary changes, contributing to the reliability and validity of information. Focus group proceedings were recorded and transcribed, which maintained credibility. Continual self-reflection for researcher bias, methodological biases and reflection on the analysis process ensured further credibility (Sandelowski, 1993) and reflexivity (Ramsook, 2018) was afforded to the study. The results of this study can be generalised to other contexts and environments (Patton, 1990), even though the findings are unique to each participant (Ramsook, 2018), and can be replicated providing there is sufficient information regarding the study's context, methodology, findings and conclusions (Creswell, 2012; Moustakas,1994) such as Arctic or Antarctic stations, space stations and other offshore and maritime facilities.

3. RESULTS

NVivo analysis revealed that the main themes that emerged throughout the discussion were the impact of COVID-19 on rosters, ability to travel to work, work hours and job continuity. Having irregular or short-term employment, and the casualisation of the workforce. In fact, casual workers tend not to want to inconvenience their employer by refusing extra shifts for fear of not receiving work in the future. Participant #4 also revealed that casual workers are less likely to stand their ground for the same

https://doi.org/10.5281/zenodo.6790705

reason. Further themes emerging from the analysis revealed a fear of making mistakes and re-injury after an accident.

The importance of Employee Assistance Programs (EAPs) were also revealed in this discussion:

> *"There's a medic, but he's there for incidents and accidents that occur out with normal operating practices, and a similar service can be provided by an EAP. We do have guys who I think have things that are affecting them externally and need to call somebody, and you need that that EAP there".*

One participant stated that making a mistake while at work was the biggest concern, stating:

> *"I think when I was sent off shore, my biggest fear I guess, was making a mistake. I think one of the more important, most important, ways of addressing that is the Stop Job Authority that everyone has. So you're expected to look out for yourself and look out for everyone else. And if people can see that you're about to do something you shouldn't, they would take you aside and have that discussion".*

The pressure to complete tasks on time was a particular factor in accident causation, with participant #8 asserting:

> *"I would argue that possibly, controversially, that a lot of the perceived pressure, which I should point out which is real, is absolutely an important part of how a lot of accidents happen. People perceive that they have to get their job done. They don't want to speak up, they want to get after it. They want to be as fast as they can, as quick as they can. They don't realise really, that's secondary to people not getting hurt, but that comes from lump sum contracts. The companies are getting lump sum contracts and the contractors that bid on them as cheap as possible and the faster they go the more money they make".*

When there is a lack of employment, skills and qualifications are unable to be maintained and it is very costly (e.g. participant #4 stated it was $15,000 for one 'ticket') to obtain these again. Participant #4 stated that when they were unable to maintain up-to-date qualifications, this results in a loss of relevant skills required for the position. Job uncertainty compounded the anxiety felt by the loss of up-to-date knowledge and skills, particularly as updating these was an unlikely option for employees due to their high cost.

Returning to work after being injured caused psychological stress to employees due to a fear of re-injury. When returning to work, a loss of support during recovery was a distressing factor. Participant #2 noted:

> *"Returning to 12-hour work days, back into work jargon again, obviously missing family and that support that they had at home while they were recovering, whether it be physio, GP, and I think that that's a big one I guess, and depending on how long they were away for and I think possibly things that could assist could be doing a bit of a hand over in advance over the phone with team members, trying to catch up and just overall prepared to go back into that work environment".*

It was recommended by participant #2 that employees returning to work from psychological injuries should be aided by a handover process in advance before their full return to work, to assist in preparing their return to the work environment. This is in keeping with the process for return to work after

https://doi.org/10.5281/zenodo.6790705

physical injury, where employees may be awarded light duties until they are declared fit to work in their usual role (participant #8).

As part of the anxieties around returning to work, the fear of re-injury was a major contributor in #7's experience of returning to work offshore:

> *"Overcoming the fear of a recurrence of the injury, for example: someone injured due to a dropped object, or fall form height may be more hesitant to perform the same role due to a lack of confidence, or faith in equipment, due to the injury".*

Last minute changes to offshore rosters have been frequent, particularly since the start of the COVID-19 pandemic. Participant #8 highlighted that extended work rosters were difficult to cope with emotionally:

> *"If you're going out for a two-day job and it became seven days, man it was painful right? It was really, really, really hard. It's only like five more days and I did three months a couple of times you know, you get home a bit frazzled".*

One participant stressed the importance of resilience, especially in light of recent changes in rosters due to the pandemic. Organisations should promote of self-awareness and enable employees to recognise stressful factors or events and their sources, ensuring a proactive approach to psychological support, rather than responding to incidents after the event. Wellbeing interventions identified included presentations and literature, supervisor support and a gradual reintegration into work for those with physical and psychological injuries.

Participant #8 went on to identify mental resilience as a protective factor in dealing with last-minute modifications to rosters, although believed this to be relatively lacking in some employees. Confirming the literature, participant #7 stated:

> *"I think a lot of the problems at the moment, not stemming from how the roster is, it's more how the rosters are going with COVID, how we're having to cope with COVID, going through with this, where people are having to stay behind or they're being asked to come back because so and so can't get in or whatever you know, because you have to keep those skills up and also for the people that can't get in there, it's that mental health, the mental issues - they're upset that they can't get there. What's going to happen to my job"?*

Participants stated that there remains room for improvement in internet and communications for offshore workers. Several of the discussion group members who were offshore at the time of interview were affected by poor internet connections. Other participants who were onshore expressed their frustration with disrupted internet services offshore, revealing that during peak hours, the quality of internet was very poor.

Fatigue results in diminished attention, caused by shift rotations patterns duration of swings, reduction in alertness. Participants identified that it was important to identify whether employees are fatigued or tired, rather than experiencing the symptoms of poor mental health, as sometimes workers may just need additional time to recover or get themselves together.

Participants described the effect of stigma and lack of support, which prevents employees from seeking help, particularly in a male-dominated environment. Participant #5 perceived that the offshore working environment still retained an air of machismo:

> *"The cowboy macho culture that comes with that environment. You're expected to behave a certain way in. Follow certain etiquette. And sometimes that can cause mental stressors on people who might not react as well. So I think having offshore psychologist plays a big part in that as well, making sure you have someone that you can talk to openly and not be judged".*

However, participant #7 was positive about the changes they had seen in the industry:

> *"There is still the "I'm okay, don't worry", but with the literature and presentations on board, generally we do tend to look out for each other more, and help our mates if we see that they are a bit down. Added to the fact that they know that they can talk to someone in confidence. I think at our place of work, the old adage of "toughen up" has been replaced with RUOK".*

Good employer-employee relations are vital to address problems in the work environment. It was identified that consistent top-down messaging about mental health remains important. The reframing of thoughts and thought processes may be beneficial in fostering self-awareness in order to identify the source of certain stressors which result in psychological distress, preventing negative thoughts from worsening. Participant #1 shared:

> *"Oftentimes it's important to be able to recognise when you are in a state that you might need to catch yourself and reframe your thoughts, because oftentimes it's the individual and they may not be willing to actually share that. So if you have, I guess we need some guidance material or something to be able to, you know, help manage our own and then obviously have a have another course of action to speak with someone, should we, you know, need additional assistance but yes, some practical ideas, I think to help you know, recognise when there is a problem".*

4. DISCUSSION

The focus group discussion provided insights into psychosocial stressors for offshore oil and gas employees. The findings revealed that rosters were a major theme in factors causing psychological distress and drew attention to the disruption in rosters and work cycles caused by the COVID-19 pandemic. In particular, rosters have been extended, where some participants were found to be working 5 weeks on and 5 weeks off, but during onshore leave would frequently be recalled offshore to work. Long and uneven rosters have been shown to result in anxiety (Berthelsen et al., 2015; Pavičić Žeželj et al., 2019; Torquati, 2019) and depression (Berthelsen et al., 2015; Torquati, 2019). In 2020, NOPSEMA issued a safety alert in response to roster changes brought in by moderators during the height of the pandemic. Concerns were raised around negative effects on employee mental health such as depression and anxiety, fatigue and heightened risk of major accidents. Accident involvement and incidents of near-misses (Nielsen et al., 2013) are a source of distress.

Contractors and casual workers are more likely to experience job uncertainty, which is a known cause of stress (James et al., 2018; Parker et al., 2017; Sutherland & Flin, 1989). Participant #4 stressed numerous times throughout the discussion that permanent contracts for workers would be more beneficial to mental health, a finding confirming the Sampson and Ellis (2020) study that looked at seafarer's mental wellbeing.

Participant #1 explained that at one point, the rostered offshore cycle was 8 weeks, with 8 days for onshore leave, followed by another 8 weeks working offshore significantly affecting time spent at home with family and friends. This would impact the employee's home life, where long periods away from home worsen the adaption period in the initial days of offshore leave (Mette et al., 2019),

https://doi.org/10.5281/zenodo.6790705

lengthen the recovery period (Parker et al., 2018), disrupt sleep cycles, as participant #1 worked 12 hour shifts that were blocks of day work followed by blocks of night work (Parkes et al., 2005) and cause fatigue, particularly for workers on night shift, which can result in a decrease in the enjoyment of home leave (Parker et al., 2018). This is partly due to the effects of a disruption in circadian rhythm, leaving employees feeling disconnected from their families (Parkes, 2005). The typical end of shift practice of calling family is made more stressful by intermittent internet access. As Henry et al. (2013) and Parker et al. (2018) found, mental wellbeing rests significantly on being able to communicate with family or friends. Not surprisingly, anxiety levels and stress increase when there are disruptions in these connections.

Fatigued or stressed employees should undergo a more gradual return to work, where the reduction in support from friends and family will have less of a devastating effect. Workers are sometimes given the opportunity to return to their accommodation to rest or have some breathing space. There are many inherent risks associated with offshore work, many of which are simply unavoidable. Participants identified further opportunities for improvement, including screening through psychometric testing, thus eliminating those not suited to the offshore work environment. A combination of psychology and business methods which are used when companies seek a particular set of skills and values or wish to assess suitability to a role, psychometric testing can accurately and validly capture valuable individual qualities such as resilience, coping skills and emotional intelligence (Caska, 2019). Participant #8 agreed that some aspects of offshore work needed to be acknowledged as being part of the job and that not all people may not be suited to the offshore work environment.

Constant changes are a factor that employees must adapt to and organisations are urged to highlight the fundamental ability for employees to have the capacity to deal with unexpected events and changes (Kuntz et al., 2016; Luthans et al., 2006, cited in Tonkin et al., 2018; Tonkin et al., 2018). Moreover, the long-term trajectory of the pandemic means that resilience is an essential personal factor that will be advantageous in uncertain times. Resilience is a central element of how organisations adapt, especially during uncertain environments (Tonkin et al., 2018). Participant #4 highlighted several times that the impermanent nature of the work was a major source of stress, a finding Matthews et al. (2021) reported, which resulted in employees questioning the reliability of the ongoing support of colleagues.

Organisations are encouraged to invest in resilience-building programs and interventions, while employees are urged to respond favourably to wellbeing and resilience-building projects (Tonkin et al., 2018), ensuring a shared obligation to commit to a supportive yet resilient work culture and environment (Sampson & Ellis, 2020). One suggestion was to incorporate resilience building as part of the toolkit, as a component of employee resources, with the aim of building on psychological endurance and adaptability to deal with unplanned negative events.

Premji (2018) states that employment may be considered precarious if there are irregular or unusual work schedules, a hazardous work environment, unreliable income or if employees are working for several different employers. Due to the COVID-19 pandemic, job security has become a major concern for offshore oil and gas workers, where border closures and travel restrictions have resulted in loss of employment.

Lack of support and stigma are still preventing employees from seeking help (Gardner et al., 2018), and it is crucial that employees are able to recognise the symptoms and signs of poor mental health or distress. Organisations can provide guidance material to employees to help them identify psychological stressors and to understand their symptoms, which would reduce stigma (Bowers et al., 2018; Henry et al., 2013). As well as awareness of mental wellness (participant #1), organisations should promote physical wellness (participants #3 and #5) along with opportunities for physical activity (Cotton, 2006),

https://doi.org/10.5281/zenodo.6790705

provide psychological support (participant #6) and stress management options. Participant #1 specifically made reference to what Greden et al. (2019) term ‘primary prevention efforts’ (p. 7), which are proactive measures designed to employees becoming exposed to a known hazard, or can aim to build resilience or tolerance. Talks can be given about many subjects such as sleep, stress and the management of stress, nutrition, physical exercise and peer support (Greden et al., 2019). Outcomes from Parikh et al.’s (2018) school-based depression prevention program showed an improvement in awareness and attitudes towards depression, as well as reducing stigma. The intervention also helped participants feel more confident in identifying depression in peers and increased intentions to seek help.

Rather than single out individual employees for interventions, which may raise concerns around stigma, or run the risk of missing an at-risk individual, Taubman et al. (2019) suggest that interventions should be universal, provided to all employees, regardless of whether they are suffering from or are likely to suffer from poor mental health. One of the most crucial elements of preventative measures is the reduction of stigma (Greden et al., 2010), and applying universal measures to the workforce reduces stigma to individual employees due to every member of staff being involved, while also avoiding the distress help-seeking in such a male-dominated environment may cause (Battams et al., 2014). The added benefit is that those who may already be suffering from poor mental health but do not recognise their symptoms as unusual or are reluctant to seek help are captured where they may have been missed (Taubman et al., 2019). Clarifying Greden et al.’s (2010) emphasis on reducing stigma, participant #5 confirmed that employees were expected to behave in a certain way in the male-led culture of the offshore oil and gas working environment, and that this affected their help-seeking behaviour, a finding published by Bjerkan (2010), Evans-Lacko & Knapp (2014) and Henry et al. (2013). Organisations are more likely to succeed tackling poor mental health in the workplace if they can reduce or eliminate stigma (participant #7), as well as see improved rates of the reporting of physical injuries (participant #8), supporting the findings of Bjerkan (2010) and Henry et al. (2013).

Suggestions for improvement focus on removing the stigma around mental health and seeking help for psychosocial issues, while also improving employee resilience, in keeping with organisational resilience. Behaviour modification, role-playing exercises, stress management, physical exercise and an improvement in the psychosocial workplace environment and culture were some other suggestions from participants (participants #1, #2, #3, #4 and #5).

While mental health screenings and programs are a direct cost to organisations, the indirect negative costs of not implementing proactive strategies for mental wellbeing are absenteeism, inability to focus, loss of production and a higher likelihood of making mistakes. The cost of screening for depression for example is significant, yet early recognition of poor mental health would reduce the costs associated with depression and is something workplaces have the potential to achieve, which would result in the prevention of depression as well as improved outcomes for those who already have depression. Furthermore, the financial burden from absenteeism, inattention at work and decreased levels of production are a far greater economic burden (Grazier, 2019). Poor mental health in the workplace has resulted in economic effects that Greden et al. (2019) find “complex and disturbing” (p. 5).

In other countries, such as the UK (Knapp et al., 2011) and Germany (Evans-Lacko & Knapp, 2014), screening in the workplace is cost-effective for organisations and healthcare systems alike. The numerous costs associated with depression alone are considerable yet underestimated (Grazier, 2019). However, increased economic participation from individuals with poor mental health would generate $1.3 billion per year (The Productivity Commission, 2020).

https://doi.org/10.5281/zenodo.6790705

The EAP has been highly effective and generally well-received throughout the pandemic employees (Dickson-Swift et al., 2014; Hughes & Fairley, 2021), where the program has adapted to include supportive solutions in keeping with social distancing and lockdown guidelines. Adoption of methods for virtual communication such as Zoom, counselling via video and telephone, a hotline for those in crisis, management-identified at-risk employees and text messaging (Hughes & Fairley, 2021). EAPs are effective in assisting employees to manage personal issues (Kirk & Brown, 2003). These programs should have the support of management, otherwise they are less likely to be welcomed by employees or result in successful outcomes. Interventions which enable employees to feel motivated and appreciated or present socialisation opportunities are more likely to be valued by employees (Dickson-Swift et al., 2014). Some workers are unaware of EAPs within their organisation, or may distrust their independence or effectiveness. In combination with embarrassment at being unable to cope and a tendency to internalise problems, EAPs are underutilised (Matthews et al., 2021).

5. CONCLUSIONS

The focus group discussion demonstrated that the main psychosocial risk factors and hazards for offshore oil and gas workers were changes in rosters, difficulties in returning to work, fear of accidents and reinjury and job uncertainty. Stigma was identified as a significant factor in preventing employees from seeking help for poor mental health. On an individual level, recommended actions included recognising when there is a problem and reframing thoughts and thought processes, which can be encouraged through organisational guidance material. On an organisational level, resilience-building interventions and proactive wellbeing programs as well as a supportive management are recommendations that emerged from this study.

Taking into account the increase in depression, anxiety and suicides in the FIFO industry over the past decade, this study is both timely and important. Furthermore, the economic toll of poor mental health can be mitigated through workplace interventions identified by industry professionals and are available for implementation within the offshore oil and gas working environment.

6. LIMITATIONS

The focus group was originally scheduled to last one hour. However, the multiple voices and viewpoints did cause the discussion to overrun by 30 minutes. Some questions therefore did not generate ample data to analyse. This was counteracted by asking each participant if they wanted to add anything to answer the questions where they had not given an answer when the transcripts were returned to participants for checking. The participants did not appear to be vulnerable to the negative aspects of focus groups noted by Carey and Smith (1994), such as the desire to conform or concerns around censorship. Conversation was free-flowing and relaxed, with participants respectful of others' wishes and attempts to speak.

REFERENCES

Australian Government. Productivity Commission (2020). *Mental health inquiry report* (Volume 1 no 95). https://www.pc.gov.au/inquiries/completed/mental-health/report

Battams, S., Roche, A. M., Fischer, J. A., Lee, N. K., Cameron, J., & Kostadinov, V. (2014) Workplace risk factors for anxiety and depression in male dominated industries: a systematic review. *Health Psychology and Behavioral Medicine: An Open Access Journal*, *2*(1), 983-1008. doi: 10.1080/21642850.2014.954579

Bergh, L. I. V., Hinna, S., Leka, S., & Jain, A. (2014). Developing a performance indicator for psychosocial risk in the oil and gas industry. *Safety science*, *62*, 98-106. doi: 10.1016/j.ssci.2013.08.005

https://doi.org/10.5281/zenodo.6790705

Berthelsen, M., Pallesen, S., Bjorvatn, B., & Knardahl, S. (2015). Shift schedules, work factors, and mental health among onshore and offshore workers in the Norwegian petroleum industry. *Industrial Health, 53*, 280–292. doi: 10.2486/indhealth.2014-018

Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: A tool to enhance trustworthiness or merely a nod to validation? *Qualitative health research*, *26*(13), 1802–1811. doi: 10.1177/1049732316654870

Bjerkan, A. M. (2010) Health, environment, safety culture and climate – analysing the relationships to occupational accidents. *Journal of Risk Research, 13(*4), 445-477. doi: 10.1080/13669870903346386

Bowers, J., Lo, J., Miller, P., Mawren, D. & Jones, B. (2018). Psychological distress in remote mining and construction workers in Australia. *Medical Journal of Australia*, *208*(9), 391-397. https://doi.org/10.5694/mja17.00950

Brannen, J. (2005) Mixing methods: The entry of qualitative and quantitative approaches into the research process. *International Journal of Social Research Methodology, 8*(3), 173-184. doi: 10.1080/13645570500154642

Carey, M. A., & Smith, M. W. (1994). Capturing the group effect in focus groups: A special concern in analysis. *Qualitative health research*, *4*(1), 123-127. doi: 10.1177/104973239400400108

Caska, B. (2019). Psychometrics at work: How to ensure test results you can trust. *DBS Business Review, 3*, 73-81. doi: 10.22375/dbr.v3i0.60

Commission for Occupational Safety and Health (2019). *Mentally healthy workplaces for fly-in fly-out (FIFO) workers in the resources and construction sectors – code of practice*. Department of Mines, Industry Regulation and Safety, Western Australia. https://www.commerce.wa.gov.au/publications/mentally-healthy-workplaces-fly-fly-out-fifo-workers-resources-and-construction-sectors

Cotton, P. (2006). Management of injured workers with psychosocial barriers. *Australian family physician, 35*(12), 958-961. https://search-informit-com.au.dbgw.lis.curtin.edu.au/documentSummary;dn=360983219989263;res=IELHEA

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. SAGE Publications. http://link.library.curtin.edu.au/p?pid=CUR_ALMA51116644810001951

Creswell, J. W. (2012). *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (4th ed.). Pearson. http://link.library.curtin.edu.au/p?pid=CUR_ALMA51188663530001951

Creswell, J. W. (2014). *A concise introduction to mixed methods research*. SAGE Publications.

Crouch, M., & McKenzie, H. (2006). The logic of small samples in interview-based qualitative research. *Social Science Information*, *45*(4), 483–499. https://doi.org/10.1177/0539018406069584

Dickson-Swift, V., Fox, C., Marshall, K., Welch, N., & Willis, J. (2014). What really improves employee health and wellbeing: Findings from regional Australian workplaces. *International Journal of Workplace Health Management*, *7*(3), 138-155. doi: 10.1108/IJWHM-10-2012-0026

Evans-Lacko, S., & Knapp, M. (2014). Importance of social and cultural factors for attitudes, disclosure and time off work for depression: Findings from a seven country European study on depression in the workplace. *PLoS One*, *9*(3). doi: 10.1371/journal.pone.0091053

Flick, U. (2007). *Managing quality in qualitative research*. SAGE Publications. https://www.doi.org/10.4135/9781849209441

Gardner, B., Kristie-Lee Alfrey, Vandelanotte, C., & Rebar, A. L. (2018). Mental health and well-being concerns of fly-in fly-out workers and their partners in Australia: A qualitative study. *BMJ Open*, *8*(3). doi: 10.1136/bmjopen-2017-019516

Grazier, K. L. (2019). The economic impact of depression in the workplace. In M. B. Riba, S. V. Parikh & J. F. Greden (Eds.), *Mental health in the workplace: Strategies and tools to optimize outcomes* (pp. 1-16). Springer. doi: 10.1007/978-3-030-04266-0_1

Greden, J. F., Garcia-Tosi, R., & Harrington, A. W. (2019). Healthy minds at work: Challenges and strategies for businesses. In M. B. Riba, S. V. Parikh & J. F. Greden (Eds.), *Mental health in the workplace: Strategies and tools to optimize outcomes* (pp. 1-16). Springer. doi: 10.1007/978-3-030-04266-0_1

Greden, J. F., Valenstein, M., Spinner, J., Blow, A., Gorman, L., Dalack, G., Marcus, S., Kees, M. (2010). Buddy-to-Buddy, a citizen soldier peer support program to counteract stigma, PTSD, depression, and suicide. *Annals Of The New York Academy of Sciences, 1201*(1), 90-97. doi: 10.1111/j.1749-6632.2010.05719.x

Henry, P., Hamilton, K., Watson, S., & McDonald, M. (2013). FIFO/DIDO mental health research report 2013. *Perth: Lifeline*.

Hughes, D. & Fairley, A. (2021) The COVID chronicles: An Employee Assistance Program's observations and responses to the pandemic. *Journal of Workplace Behavioral Health, 36*(3), 177-196. doi: 10.1080/15555240.2020.1844569

James, C., Tynan, R., Roach, D., Leigh, L., Oldmeadow, C., Rahman, M., & Kelly, B. (2018). Correlates of psychological distress among workers in the mining industry in remote Australia: Evidence from a multi-site cross-sectional survey. *PLoS ONE, 13*(12): e0209377. doi:10.1371/journal.pone.0209377

Knapp, M., McDaid, D., & Parsonage, M. (2011). Mental health promotion and mental illness prevention: The economic case. Department of Health. https://www.gov.uk/government/publications/mental-health-promotion-and-mental-illness-prevention-the-economic-case

Kirk, A. K., & Brown, D. F. (2003). Employee assistance programs: A review of the management of stress and wellbeing through workplace counselling and consulting. *Australian Psychologist, 38*(2), 138–43. doi: 10.1080/00050060310001707137

Landon, L. B., Douglas, G. L., Downs, M. E., Greene, M. R., Whitmire, A. M., Zwart, S. R., & Roma, P. G. (2019). The behavioral biology of teams: Multidisciplinary contributions to social dynamics in isolated, confined, and extreme environments. *Frontiers in Psychology, 10*, 2571. doi: 10.3389/fpsyg.2019.02571

Liamputtong, P. (2011). Virtual focus groups. In *Focus group methodology: Principles and practice* (pp. 149-164). SAGE Publications Ltd. https://www.doi.org/10.4135/9781473957657

Long T., & Johnson, M. (2000). Rigour, reliability and validity in qualitative research. *Clinical Effectiveness in Nursing, 4*(1), 30-37. doi:10.1054/cein.2000.0106. https://doi.org/10.1054/cein.2000.0106

Matthews, L. R., Gerald, J., & Jessup, G. M. (2021). Exploring men's use of mental health support offered by an Australian Employee Assistance Program (EAP): Perspectives from a focus‑group study with males working in blue‑ and white‑collar industries. *International Journal of Mental Health Systems, 15*(68), 1-17. doi: 10.1186/s13033-021-00489-5

Mette, J., Robelski, S., Kirchhöfer, M., Harth, V., & Mache, S. (2019). Living the 14/14 schedule: Qualitative analysis of the challenges and coping strategies among families of offshore wind workers. *International Journal of Environmental Research and Public Health, 16*(2). doi: 10.3390/ijerph16020241

Morse, J. M. (1994). Designing funded qualitative research. In Norman K. Denzin & Yvonna S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp.220-35). Sage.

Moustakas, C. (1994). *Phenomenological research methods*. SAGE Publications, Inc. https://www.doi.org/10.4135/9781412995658

Murray, P. J. (1997). Using Virtual Focus Groups in Qualitative Research. *Qualitative Health Research*, *7*(4), 542–549. https://doi.org/10.1177/104973239700700408

National Offshore Petroleum Safety and Environmental Management Authority (2020). COVID-19 roster changes. https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A724699.2.pdf

Neis, B., Neil, K., & Lippel, K. (2020, April). *Mobility in a pandemic: COVID-19 and the mobile labour workforce* (Working Paper). https://www.onthemovepartnership.ca/wp-content/uploads/2020/04/COVID-and-Mobile-Labour-Force-Working-Paper.pdf

Nielsen, M. B., Tvedt, S. D., & Matthiesen, S. B. (2013). Prevalence and occupational predictors of psychological distress in the offshore petroleum industry: A prospective study. *International Archives of Occupational and Environmental Health, 86*(8). 875-885. doi: 10.1007/s00420-012-0825-x

Parikh, S. V., Taubman, D. S., Antoun, C., Cranford, J., Foster, C. E., Grambeau, M., Hunter, J., Jester, J., Konz, K., Meyer, T., Salazar, S., & Greden, J. F. (2018). The Michigan peer-to-peer depression awareness program: School-based prevention to address depression among teens. *Psychiatric Services, 69*(4), 487-491. doi: 10.1176/appi.ps.201700101

Parker, S., Fruhen, L., Burton, C., McQuade, S., Loveny, J., Griffin, M., Page, A., Chikritzhs, T., Crock, S., Jorritsma, K., & Esmond, J. (2018). *Impact of FIFO work arrangements on the mental health and wellbeing of FIFO workers*. Centre for Transformative Work Design. https://www.mhc.wa.gov.au/media/2547/impact-of-fifo-work-arrangement-on-the-mental-health-and-wellbeing-of-fifo-workers-full-report.pdf

Parker, S. K. Morgeson, F. P., & Johns, G. C. (2017). One hundred years of work design research: Looking back and looking forward. *Journal of Applied Psychology, 102*(3), 403-420. doi: 10.1037/apl0000106

Parkes, K. R. (1992). Mental health in the oil industry: A comparative study of onshore and offshore employees. *Psychological Medicine, 22*, 997-1009. doi: 10.1017/S0033291700038563

Parkes, K. R., Carnell, S. C., & Farmer, E. L. (2005) 'Living two lives'. *Community, Work & Family, 8(*4), 413-437. doi: 10.1080/13668800500251755

Pavičić Žeželj, S., Cvijanović Peloza, O., Mika, F., Stamenković, S., Mahmutović Vranić, S., & Šabanagić Hajrić, S. (2019). Anxiety and depression symptoms among gas and oil industry workers. *Occupational Medicine*, *69*(1), 22–27. doi: 10.1093/occmed/kqy170

Premji, S. (2018). "It's totally destroyed our life": Exploring the pathways and mechanisms between precarious employment and health and well-being among immigrant men and women in Toronto. *International Journal of Health Services 48*(1), 106-127. doi: 10.1177/0020731417730011

Ramsook, L. (2018). A methodological approach to hermeneutic phenomenology. *International Journal of Humanities and Social Sciences, 10*(1), 14-24. https://www.researchgate.net/profile/Leela-Ramsook/publication/323687948_A_Methodological_Approach_to_Hermeneutic_Phenomenology/links/5aa921fbaca272d39cd50403/A-Methodological-Approach-to-Hermeneutic-Phenomenology.pdf

Sampson, H., & Ellis, N. (2020). Stepping up: The need for proactive employer investment in safeguarding seafarers' mental health and wellbeing. *Maritime Policy & Management*, 1-13. doi: 10.1080/03088839.2020.1867918

Sandelowski M. (1993). Rigor or rigor mortis: The problem of rigor in qualitative research revisited. Advances in Nursing Science, 16. 1–8. doi: 10.1097/00012272-199312000-00002

Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretative phenomenological analysis: Theory, method, and research*. Sage. http://link.library.curtin.edu.au/p?pid=CUR_ALMA21101140930001951

Smith, J. A., & Osborn, M. (2008). *Interpretative phenomenological analysis.* In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (p. 51–80). Sage Publications, Inc. http://link.library.curtin.edu.au/p?pid=CUR_ALMA21151713410001951

Sotiriadou, P., Brouwers, J., & Le, T. A. (2014). Choosing a qualitative data analysis tool: A comparison of NVivo and Leximancer. *Annals of Leisure Research*, *17*(2), 218-234. https://doi.org/10.1080/11745398.2014.902292

Sutherland, K. M., & Flin, R.H. (1989) Stress at sea: A review of working conditions in the offshore oil and fishing industries, *Work & Stress*, *3*(3), 269-285. doi: 10.1080/02678378908251563

Taubman, D. S., Velyvis, V., & Parikh, S. V. (2019). Assessment and treatment of mood and anxiety disorders in the workplace. In M. B. Riba, S. V. Parikh & J. F. Greden (Eds.), *Mental health in the workplace: Strategies and tools to optimize outcomes* (pp. 1-16). Springer. doi: 10.1007/978-3-030-04266-0_1

Tonkin, K., Malinen, S, Näswall, K., & Kuntz, J. C. (2018). Building employee resilience through wellbeing in organizations. *Human Resource Development Quarterly, 29*(2), 107- 124. doi: 10.1002/hrdq.21306

Torquati, L., Mielke, G. I., Brown, W. J., Burton, N. W., & Kolbe-Alexander, T. (2019). Shift work and poor mental health: A meta-analysis of longitudinal studies. *American Journal of Public Health, 109*(11). doi**:** 10.2105/AJPH.2019.305278

van Manen, M. (1990) *Researching Lived Experience: Human Science for an Action Sensitive Pedagogy*. The Althouse Press. http://link.library.curtin.edu.au/p?pid=CUR_ALMA51167764310001951

Wyatt, M., & Lane, T. (2017). *Return to work: A comparison of psychological and physical injury claims. Analysis of the Return-to-Work Survey results*. Safe Work Australia. https://research.monash.edu/files/289621291/284492446_oa.pdfh

APPENDIX 1

Focus Group Interview questions

Positioning statement:

The offshore oil and gas working environment is unique and may hold many psychological stressors for employees. When considered together, these factors may pose a greater than average risk to employees' mental health and wellbeing. This discussion aims to facilitate the development of effective interview questions for the research participants of the study *Identifying Western Australian Offshore Oil and Gas Workers Mental Health Hazards and Risk Control Measures*.

Exploratory Questions:

1. In your experience are there any management practices or work organization practices that affect mining industry employees' mental health? If so please explain.
2. Do you know of any psychosocial obstacles for employees when returning to work following a work-related injury or ill health and if so how do you think that these can these be mitigated?
3. What do you think are the main types of, and causes of, mental health stressors for offshore oil and gas workers? What risk control measures do employers use for these mental health stressors and how effective do you think they are?
4. If employees have poor mental health, how does this impact on offshore employees' health and their safety?
5. Do you know of any economic effects on organizations when employees have to deal with psychosocial issues and/or poor mental health? If so, what are the economic effects?
6. What do you think are the economic effects of having good employee mental health practices implemented by the company?
7. Regarding best practice, what do you find gives the best outcomes for promoting positive mental health for employees in the workplace?
8. Where do you think that there are opportunities for improvement in promoting positive mental health practices for contractors and workers with ongoing employment in the offshore oil and gas industry?

Exit statement:

Is there anything else that you would like to add to the discussion, or anything that you feel was missed?

AUTHORS

Emma D'Antoine, B. Soc. Sci. Psychology, Master Human Rights, Ph.D. candidate in the Department of Petroleum Engineering in the Western Australian School of Mines: Minerals, Energy and Chemical Engineering, Curtin University, researching psychosocial risk factors for offshore oil and gas workers. Member Occupational health Society of Australia. Peer reviewer for Journal of Occupational and Organizational Psychology and Journal of Management and Organization.

Dr. Janis Jansz, is an Associate Professor in Occupational Health, Safety and Environmental Health in the Western Australian School of Mines: Minerals, Energy and Chemical Engineering at Curtin University in Western Australia and a Professor at the Xi'an University of Science and Technology, China. She also works for the Healthforce Group. Janis is the Director of the World Safety Organization National Office for Australia and Vice President of the Occupational Health Society of Australia. She has been awarded Life Membership of the Australian Institute of Health and Safety for many years of work improving, teaching and conducting research to advance occupational safety and health practices and for taking a leadership role the safety and health profession.

Professor Ahmed Barifcani, BSc. MSc, PhD in chemical engineering from University of Birmingham (UK), Fellow (FIChemE) and Chartered Scientist (CSci) of the Institution of chemical engineers. Also, an Associate Professor in the Western Australian School of Mines: Minerals, Energy and Chemical Engineering at Curtin University in Western Australia. Over 100 peer reviewed publications related to research in the areas of CO2 capture, flow assurance, wettability, low temperature separation processes LNG and sour gas separation. Supervision or and co-supervision of 38 PhD and MSc HDR students. Winner of the Curtin commercial innovation award in 2009 first prize.

Dr. Sherrilyn Mills, Bachelor of Business (HRM, IR), Master OSH, PhD has been involved in workers' compensation, injury management, vocational rehabilitation and occupational health and safety since 1997. Together with her extensive research and PhD on individual, organisational and psychosocial factors, that prevent return to work and post workplace injury, Sherrilyn is known as an authority in her field providing transformational change in culture, systems, engagement and in people management. Sherrilyn has established significant experience and credibility throughout her career predominantly consulting with a variety of national companies to prevent and mitigate the effects of ill-health and injuries in sectors including government, oil and gas, mining, transport and engineering.

Distinguished Professor Mark Harris, John Curtin Distinguished Professor in the School of Economics and Finance (Faculty of Business and Law), Co-Director of the Health Economics Cluster, Member of the Editorial Board of the Journal of Risk and Financial Management and has journal refereeing responsibilities on eleven other journals. Mark's research and publications have generally been in various areas of applied economics and econometrics. Mark has taught the unit of Introductory Econometrics. Publications have generally been in various areas of applied economics and econometrics.

Dr. Christopher Lagat, BSc. in Civil Engineering, MSc and PhD in Petroleum Engineering, Chartered Professional Engineer (CPEng) in Australia's National Engineering Register (NER) and a Member of the Institution of Engineers Australia (MIEAust). Has over 15 years industrial experience in oil and gas reserves evaluation, determination of potential productivity and profitability of oil and gas discoveries, civil and structural engineering design, construction supervision, projects commissioning, project management, procurement, contracts management, health, environment and safety areas. His research areas include reservoir engineering, drilling engineering, CO2 capture and sequestration, flow assurance, health and safety, decommissioning of oil and gas fields.

https://doi.org/10.5281/zenodo.6790705

World Safety Journal

A peer-reviewed journal,
published by the World Safety Organization

Journal Homepage:
https://worldsafety.org/wso-world-safety-journal/

From truck driver awareness to obstacle detection: A tiger never changes its stripes

Todd Pascoe*, Shirley McGough, and Janis Jansz
Curtin University, Western Australia

KEYWORDS

Artificial intelligence
Haul truck automation
Machine learning
Driverless technology

ABSTRACT

To inform the design of artificial intelligent systems on a mine site, incidents involving driverless haul trucks were evaluated to understand the risk implications of automation in its application. Safety-related incidents (n = 998) on a mine site in Western Australia (WA) were recorded to analyse events involving driverless and manually operated haul trucks since the operation began back in 2013. Truck incidents were evaluated and compared on their characteristics and investigation findings. From FY14 through to FY18, the incident frequency of manually driven haul trucks averaged 968 incidents per 1,000,000 hours driven, while the driverless trucks averaged 866. Driver awareness was the most frequent hazard associated with manually operated haul trucks, while haul road conditions (objects identified or not) were the most common hazard associated with automated haul trucks.

Data analysis demonstrates how driverless trucks transformed a mine site's risk profile, rather than underpin the popular notion that automation eliminates the risks associated with surface mobile equipment. Therefore, risk management should focus on enhancing users' knowledge of computer programming and machine learning techniques that is driving the most progress in industry to-date. Such a focus would legitimise the current progress of artificial intelligence and highlight the residual workload of humans whose roles are transforming and adapting to the introduction of driverless technology.

1. INTRODUCTION

Haul trucks are a vital component of a mining supply chain. They also hold the potential cause fatal incidents from unintended situations. According to the Department of Mines, Industry Regulation and Safety (2014), there were five fatal haul truck incidents in Western Australia between 2000 and 2012. Although the elimination of haul truck incidents is yet to be achieved, driverless technology is being introduced to remove human exposure to truck driving hazards. Automated systems have also been proven to be effective in reducing significant incidents (Udd, 2019). This is largely due to the fact that permission-based control systems coordinates truck movements by permitting exclusive sections to the road (Hamada & Saito, 2018).

Corresponding author: toddpascoe@hotmail.com

https://doi.org/10.5281/zenodo.6790736

Furthermore, manual equipment are provided with a system-based interface to manage haul truck interactions. Digital interfaces highlight the location of surrounding vehicles and sections of road occupied by the driverless vehicles. Despite the direct benefits of automation, new hazards and risks have emerged. These hazards and risks are unique to a driverless operation have played a role in the unconventional incident types involving driverless haul trucks (Department of Mines and Petroluem, 2015b).

The WA mining industry's risk transformation is being driven by the rapid introduction of artificial intelligence (Gray, 2019). According to recent reports, there are now more than 350 automated haul trucks in the Pilbara region (BHP, 2019; Fortescue Metals Group Limited, 2019; Jacques, 2019). There are also plans to expand BHP's driverless strategy across its entire iron ore and coal open cut operations (Palmer, 2019). Introducing automated systems, however, has already highlighted a number of important lessons (Department of Mines and Petroluem, 2014); particularly those that have already been learnt in Aviation, Maritime and Manufacturing (Dekker & Woods, 2002; Lee & Morgan, 1994; Woods, 2016). Yet, the same signs and symbols of human–machine breakdown appear to be repeating themselves—just simply in another industry context. Over the last six years, driverless haul trucks have been involved in a number of significant incidents ("BHP blames heavy rains for autonomous trucks crash," March, 2019; Department of Mines and Petroluem, 2015b; "Fortescue Metals Group auto haul truck crash Christmas Creek 'no failure' of system," February, 2019). These new types of incidents have sparked interest in the safety aspects of self-driving vehicles. More importantly, how automated systems are adapting and changing to the complex situations that arise on mine sites.

In order for driverless technology to succeed, there is an urgent need to assist the WA Mining Industry with empirical research on the risk profile changes. The WA Department of Mines, Industry Regulation and Safety published a Code of Practice surrounding the safe use of autonomous mobile equipment (Department of Mines and Petroluem, 2015a). However, like any new technology, there are limited empirical studies on the implications of its practical application. This can also be said for research publications, where driverless technology is yet to be critically evaluated in a complex mining environment. Therefore, there was a real need for this safety research. Not only to support the mining industry on their journey, but to assist academia in keeping abreast with the industry's technological innovation.

Driverless technology has so far been viewed as the solution to safety. A computerised system that can do no wrong (ADVI Hub, 2016, June 27). The assumption is that the substituting of human cognition can eliminate the risks of truck driving. Without a human, there can be no possible lapses in concentration or fatigue related events behind the wheel. A truck is expected to navigate corners and bends, while also reversing towards excavators, dump faces and drop cuts. Removing the driver effectively eliminates human exposure to high-risk tasks. Secondly, by substituting the operator, people are no longer exposed to 'hazardous' driving behaviours. The assumption is that once control is transferred to a computer, people who remain are no longer exposed to a 400-tonne haul truck. Since trucks are now given assignments, execute those instructions and performing nothing else. On that basis, the value proposition stakes up, given that these assumptions reign true. However, if automation were to eliminate the risk entirely, then there would not have been any significant incidents?

Although there are no longer people behind the wheel, the uncontrolled nature of a driverless truck incident highlights the possibilities. There are also light vehicles, dozers, loaders and excavators still operated manually on the mine. Even if driverless trucks were only involved, investigators would be hard pressed to argue how a person could not be exposed. Evaluation of risk is this new era is a real balance between foreseeability and tolerability. A bandwidth between treating every incident as severe, versus the perception that there is no risk at all. The point here, is that if systems and processes

https://doi.org/10.5281/zenodo.6790736

breakdown when humans are not involved, who is to say it would not happen when they were? This study is not a criticism of driverless technology, more the opposite. If the technology is not deeply understood, there is a real possibility that the industry could discard driverless vehicles entirely. Left flat footed on the back of the hype cycle as it stumbles through the trough of disillusionment (Panetta, 2019, August 29). There is reason why this paper is titled: "From driver awareness to obstacle detection: a tiger never changes it's stripes". The introduction of driverless technology has not eliminated safety risk, it has removed human exposure and exploited what was left. The trucks are still big, yellow and mobile: they are just now being controlled by a computer.

2. METHODOLOGY

2.1 Data Collection

The method involved collecting health and safety incidents involving manual and automated trucks. The incident data was extracted from a safety database, setting a date range from Financial Year 2014 (FY14) to 2018 (FY18). This four-year period is a reflection of WA mine sites' transition from manual to fully automated control. The transition period enabled the research to follow the full deployment of driverless haul trucks and the reverberations on safety.

Collecting raw incident data required setting specific parameters in the database. Firstly, each Department's data was selected to obtain the entire range of haul truck-related incidents. Department incident data was filtered for health, safety, environment and financial impacts. This method was adopted to ensure every incident reported could be found. Moreover, incidents that may have been incorrectly assigned impact types could be identified (i.e. environment over safety). There were also noteworthy observations made during data collection. The researcher was made aware of certain haul truck-related incidents; yet, they were unable to be locatable in database. Search functions had only been set for health and safety. It was soon found that a significant portion of driverless incidents were allocated 'financial' impacts over 'safety'. Once financial impacts were added, a number of additional haul truck incidents emerged. This observation was an interesting finding leading into the research. The discovery left the researcher asking, 'how were driverless haul trucks incidents being assessed?'

The exported information was tabled into an excel spreadsheet. Incident data was automatically tabled into various columns for every event. Columns included the incidents' unique identifier, date, department, title, investigation, severity and who it was reported by. Incident findings were obtained from the long description of the report. For example, "At approximately 10:30am DT xxxx [Dump Truck] was travelling loaded towards Pxx Rom waste dump from Ex xxxx [Excavator]. DT xxxx has encountered muddy conditions causing it to briefly lose traction and breach lane". Investigation findings were included in the original notification; certain causes were outlined in a separate report. As investigation 'root cause' types were not overly insightful, the researcher analysed and coded 1,223 incidents to identify whether a truck was involved. This interpretative process provided the platform for the data analysis.

2.2 Data Analysis

The raw nature of the data required each incident to be coded. Since there were no incident types, limited root cause category and hazards assigned, more context needed to be drawn. Therefore, data coding was undertaken to ask more investigative questions of the data set:

- Did the incident involve a truck?
- Was the truck in manual or automatic control?
- What was the incident type?

https://doi.org/10.5281/zenodo.6790736

- What was the associated hazard?
- Was the hazard new, conventional or has it transformed?

These questions not only provided more context, it enhanced the quantitative aspects of the data. For example, the analysis could determine the frequency of incident types and hazards. Calculating a frequency substantiated the impact of each occurrence and its condition. In addition, the method of coding gave rise to more structure in the data. Structure increased the researcher's understanding of the phenomenon by highlighting key themes. These themes provided a clear link between incidents and their associated hazards. For example, road conditions and network communication losses were the major contributors to truck lane breaches. Drawing the link between new, conventional and transformed hazards, which highlight the reverberations of the technology.

Driving hours were also collected in an attempt to compare manual and driverless operations. For instance, even though the manual trucks had a higher number of incidents, the number of driving hours were higher. The total number of incidents were not comparable when considering the size of each operation. Moreover, self-driving car companies are using a similar metrics to measure performance. Waymo, for example, are utilising the number of kilometres travelled to measure performance. Travel time comparisons are useful; however, caution is expressed when using it as an absolute figure to measure driverless 'safety' reliability. Driverless vehicles and their equipment failure modes are a very small component in an open, dynamic and complex environment. Therefore, the frequency of incidents should be used as indicator, not a baseline for failure modes. Nonetheless, the results provide an interesting perspective on the consequences of introducing driverless technology on a mine site.

3. RESULTS

3.1 The frequency of haul truck incidents reduced across site

The mine site's truck incident frequency significantly reduced over the four years (Figure 1). The graph highlights a 91% reduction from Financial Year 2014 to 2018. A total of 998 trucks incidents were identified in the database. The data represents incidents that occurred during the transition from manual to driverless control. Reducing the site's incident frequency was underpinned by an uplift in truck hours and a reduction in the number of incidents.

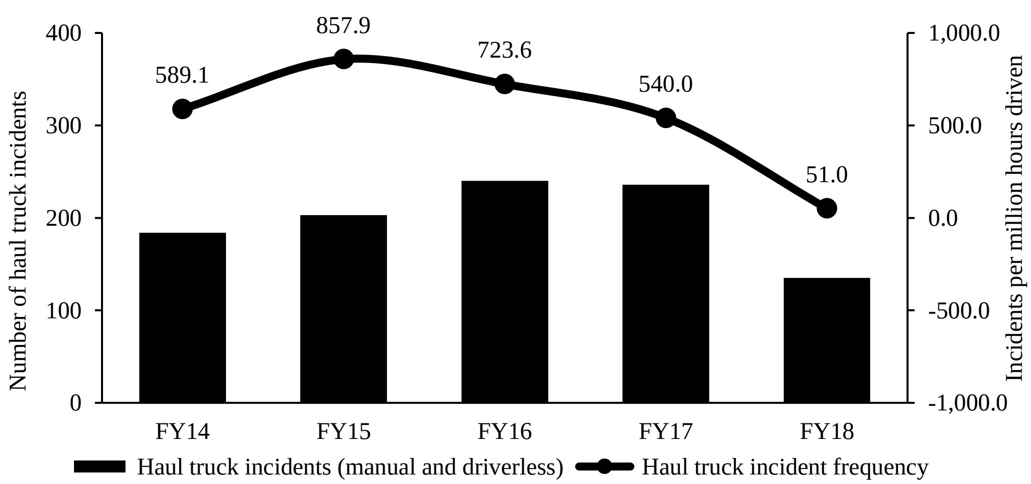


Figure 1: Site haul truck incident frequency[a]

[a] *Frequency was calculated based on the number of incidents in both the manual and driverless operation, divided by the number of hours driven, times a million.*

https://doi.org/10.5281/zenodo.6790736

The mine site's incident frequency averaged 921.4 incidents per million hours driven. Over a million truck hours were driven by both operations. The highest incident frequency was recorded in the manual operation. Manual trucks recorded 968 incidents per million hours driven. Despite manual driving hours exceeding the driverless operation, the hours did not offset the high number of incidents. Comparingly, the driverless operation registered 866 incidents per million hours driven. Although there was a year-on-year increase in the number of 'unconventional' incidents, the uplift was not substantial enough to impact the frequency. Moreover, as the driverless operation expanded, the number of hours increased exponentially. Therefore, as manual operations transferred more control, the positive impact of the driverless fleet reduced the site's haul truck incident frequency. A significant portion of incidents were reduced by removing human exposures to driving hazards. For example, trucks being heavy loading, drivers seated for long period and travelling over rough roads. Injuries to the backs, shoulder and neck were the largest contributor to truck incidents. The second most frequent incident was tray damage. The repetitive nature of loading trucks left excavators operators vulnerable to misjudging tray heights. In addition, the dust generated from the excavator had reduced operator visibility of the tray.

Procedural breaches in manual were predominately traffic management breakdowns. Positive communication breakdowns occurred when drivers had not gained permission before passing. Moreover, correct radio protocols were not utilised prior to overtaking. Priority rules were in place to give more important equipment right of way. For instance, watercarts had to give way to haul trucks. The most common breaches were truck on truck. Drivers were either unsure who took priority, had not observed oncoming traffic or forgot to give way. Secondly, working graders were the highest priority when considered working. Truck drivers had to determine whether the grader's blade was grounded. Trucks did not given way when the blade was observed to be lifted or working graders were heading in the opposite direction. Another example were truck U-turns on haul roads. U-turns were performed unassisted when the driver was lost or assigned to a new load source. Drivers were unsure of the process to block the road to prevent smaller equipment from travelling into the truck's path.

Mobile equipment were to maintain 50 metres from one another. Close interactions occurred frequently in the loading area and on intersections. While heavily focused on the task, clean-up machines lost track of their proximity to other machines. For example, while watching the blade, a grader operator reversed out in front of a haul truck. In addition, trucks drove into Active Mining Areas (AMAs) while they were not permitted. Light vehicles (LV) had closed the area to conduct workplace inspections, operator change outs or equipment breakdowns. Drivers entered the area if they did not hear the radio call or identify an LV in the area. Manual trucks were frequently made contact with haul road delineation. Trucks had either misjudged the corner or did not identify the divider. The intent of dividers are to prevent haul class equipment from cutting corners and contacting smaller equipment ("HWE Mining to face retrial over death of Adam Sargeant at Yandi mine," 2014).

Loaded haul trucks tip at the crusher or waste dump. Crusher light systems notify a driver when the bin is below threshold. A number of incidents occurred when drivers tipped on a red light. Red light tipping occurred when drivers were distracted by two-way communication, assumed the light was green or forgot about the light altogether. While trucks were tipping at the crusher, trucks had also made contact with the structure. Truck drivers either misjudged the bay width, distracted by radio communications or were visually obstructed by dust. On a waste dump, there were instances of manual trucks pushing through windrows. Windrow breaches occurred when windrows were inadequate in height or built out of incompetent material.

Operators are required to isolate trucks before entering the footprint. Truck drivers were required to enter the footprint to refuel or visually inspect the machine. Drivers entered the footprint while the machine was energised during refuelling and shift change. Isolation breaches occurred when drivers

https://doi.org/10.5281/zenodo.6790736

attended to oil leaks, material hang up or possible mechanical issues. During driver interchange, trucks had made contact with the boarding ramps. When attempting to park beside the ramp, drivers misjudged the distance from the truck and to the boarding ramp.

Table 1. Manual haul truck incidents

Incident Type	Description	Total (#)	(%)
Driver injury	Harm was sustained in association with a truck (i.e. hurt while on/in a truck)	136	24.0
Truck contact	Truck was impacted by another machine (i.e. excavator)	135	23.9
Procedural breach	Tuck did not follow the procedure (i.e. entering controlled mining area)	102	18.0
Priority rules breach	Truck did not give way to another truck who had way of right	74	13.1
Delineation contact	Truck made contact with a road divider	54	9.5
Crusher contact	Truck came in contact with a crusher while attempting to tip	24	4.2
Truck slide	Truck slid on the haul road (i.e. wet road or low-grade road base)	20	3.5
Windrow breach	Truck pierced through the separation windrow on the dump	5	0.9
Boarding ramp damage	Truck contacted the ramp while swapping out the operator out of cab	5	0.9
Fuel hose damage	The hose used to fuel the truck was damaged	3	0.5
Truck alarm	An alarm was sounded due to a maintenance issue	3	0.5
Boom gate damage	The gate to prevent entry into mining area was damaged by a truck	1	0.2
Exposed edge	A truck was exposed to an open tip head in the pit	1	0.2
Fume inhalation	Truck driver inhaled diesel fumes from the machine	1	0.2
Rock spillage	Rocks were spilled on the road from a loaded haul truck	1	0.2
Uncontrolled movement	Truck had rolled or moved unintentionally without control	1	0.2
Total		566	100.0

3.2 Despite direct safety benefits, unconventional incident types emerged

Naturally, as a mining operation expands, the number of workplace incidents will increase. However, a year-on-year increase in the number of unconventional event types is vastly different. Particularly when those incidents have never been encountered before. Truck slides occurred in manual operations; however, the incident pathways in driverless were novel and more frequent. Lane breaches were caused by communication losses, speed zones or wet road conditions. Loss of network immediately stopped trucks and frequently caused lane breaches. Similarly, in the early stages, when a 20 km/h zone was reached, a truck would immediately reduce its speed from 60 km/h. In addition, when roads were wet, the situation is compounded. Driverless trucks are unable to 'see' wet roads. Instead, trucks relied upon traction and speed zones to be put in place by humans. Road objects that were suddenly detected caused a number of trucks to slide out of lane. Since the technology is yet to distinguish between objects, trucks cannot determine the difference between tumble weed, centre dividers and non-site aware vehicles.

Processes breaches were quite similar to procedural breaches. Yet, the processes were residual human tasks based on design limitations. Automation did not eliminate trucks from tipping on red lights. Mine Control were still required to remotely tip failed truck assignments. Therefore, controllers needed to observe the lighting system before overriding the truck. Remotely tipping reinforced the difference between available and observable information. Although automation successfully prevented trucks from entering closed AMA's, the system relied heavily on LV's to virtually lock the area. Driverless trucks drove into AMA's where light vehicles forgot to lock or engage the button effectively. Vehicles and equipment also overtook stationary trucks before taking control of them. Driverless trucks can move at any time and have limited detection capability from the side. Despite this, proximity detection enabled driverless trucks to determine the location of other vehicles. In addition, predicted travel capability detects vehicles headed for truck routes much earlier than before. Therefore, driverless trucks could be more adaptive, reducing their speed prior to the interaction. This capability had only been introduced into the WA Mining Industry post the watercart collision (Department of Mines and Petroleum, 2015b).

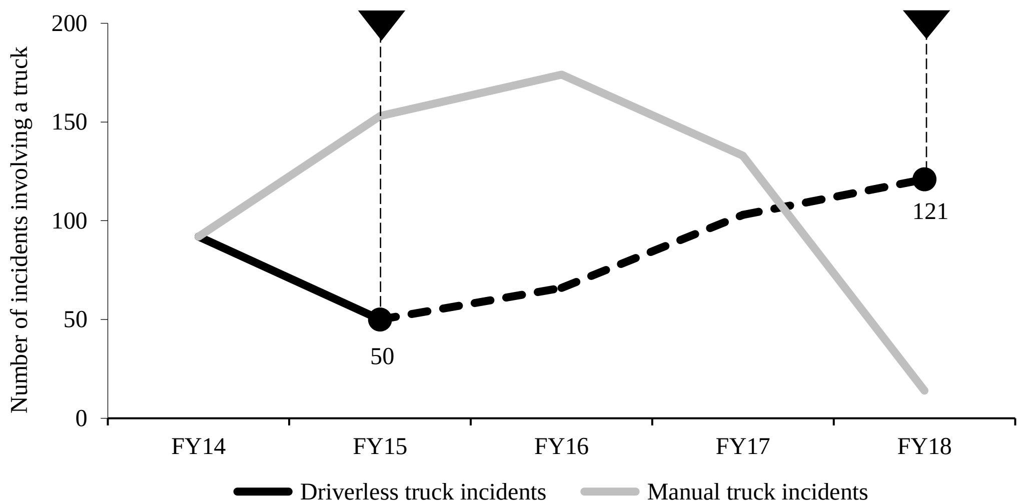


Figure 2. Increase in driverless truck incidents as manual incidents decline

Permission-based control simplified priority rules and was far more passive. As a result, priority rules breaches between haul trucks were reduced to zero. However, despite engineering controls, interactions remained administrative for manual equipment. Clean-up machines recorded the highest number of incidents. Dynamic lanes are able to flip from one side of the excavator to another. Dozer operators not watching in-cab displays were surprised by lanes generated into their work area. Trucks effectively 'sneak up of them'. Equipment icons had also flipped to cause reactions to driverless trucks. This was evident when clean-up machines were continuously moving. Truck damage remained present within the operation. A previously stated, removing the truck driver reduced the consequence, however truck trays were still damaged. Conventional tyre separation and equipment breakdowns existed. It had simply transformed the way the trucks responded to the situation. Similar to material in loading and dumping areas. However, if the material was not surveyed into the mine model, the risk was that trucks could collide with the stockpile. In addition, full dump locations meant that trucks would attempt to reverse over the material already tipped; resulting in truck damage. Vehicles under escort were also unable to identified by the trucks. A broken escort left non-site aware vehicles with fewer layers of protection, even though trucks recognised their vehicle as an object to prevent colliding.

Personal injuries had been sustained during truck refuelling, truck testing and fault findings. Since drivers were tasked to refuel their own truck, injuries during manual refuelling were captured. A shoulder injury in driverless was sustained when lifting the hose into place. During truck testing, a production technician was injured when the retarder was engaged instantly. And after having difficulties mode changing a truck, a technician put their hand into a rotating LiDAR when it appeared to be stationary. Recovering trucks signified the retrieval of trucks from bogging after travelling

https://doi.org/10.5281/zenodo.6790736

through wet roads. Moreover, if the lane had not been surveyed then the area was permissible. Trucks had reversed over windrows that had not been surveyed into the virtual model. The truck detects the windrow initially, however once overridden; the truck attempted to achieve the dump location. However, to system technicians, it can appear to be no object in the path at all. This was observed in the survey mismatches. Trucks were found to be using dump plans based on the wrong survey data, which did not reflect the physical mine. Automation had prevented trucks from contacting the crusher with pre-defined lanes. Crushing facilities were not dynamic areas like waste dumps and loading areas. However, this did not prevent rocks from damaging the crusher when tipping out of the tray.

Table 2. Driverless truck incidents

Incident Type	Description	(#)	(%)
Lane breach	Truck had drifted outside of the assigned pathway	190	44.0
Proximity detection	Detection of potential pathway collision with machine	135	31.3
Truck damage	Truck has contacted or been contact by another machine	32	7.4
Process breach	System-based task did not comply with the procedure	31	7.2
Object detection	Identified object and stopped suddenly	14	3.2
Reversed into material	Truck reversed into a dump pile	7	1.6
Broken escort	Non-site aware vehicle became separated from escorts	4	0.9
Technician injury	Person was injured while attending to a truck	3	0.7
Production loss	Truck fleet down for extended period of time	3	0.7
Bogged truck	Caught in wet ground material	2	0.5
Uncontrolled movement	Rolling backwards or forwards uncontrollably	2	0.2
Windrow breach	Truck protruded through windrow on dump	2	0.2
Truck collision	Truck was had contact another truck	1	0.2
Ore tipped on waste	Ore material was tipped onto a waste dump	1	0.2
Rock breach bund	Rock tipped over a waste dump and breached bund	1	0.2
Procedural breach	A procedure was not followed in the execution of a task	1	0.2
Ore tipped on wrong pile	Incorrect material type was tipped on a stockpile	1	0.2
Failed truck assignment	Truck unable to execute given assignment	1	0.2
Crusher contact	Rock fell from tray and damaged the crusher	1	0.2
Total		432	100.0

3.3 Unconventional incidents driven by new and transformed hazards

The emergence of unconventional incidents types created a new risk profile. A profile that comprised of risks that not only transformed hazards, they formed new ones as well. Transformed hazards were those that existed in manual operations but simply changed shape. Key differences were in pathway to failure and how the trucks approached the situation. For example, wet roads existed in manual and driverless operations. However, both systems managed them in vastly different ways. A driver could easily spot increases in rain fall, adjusting their speed and drive to conditions. Truck drivers also spoke amongst themselves to be mindful of certain road conditions on the circuit. Driverless trucks, on the other hand, relied upon traction controls and system users to install speed zones on impacted areas. The operation's 'eyes and ears' were effectively replaced with 'satellites and sensors'.

Driver awareness was entirely removed and replaced with road conditions. It is quite fascinating how the attention had shifted from the person to the environment. Road conditions were always there; however, it appears that truck capabilities were engineered, they were accepted. Load unit interaction remained, simply relocated the consequence. Without drivers, the ergonomics of sitting behind the wheel was no longer the focus. Attention soon turned to road objects and clean-up machines. Since the trucks were not technically capable of distinguishing between objects, the focal point changed to removing the objects. Haul road interactions were remained, however there were no longer radio calls.

https://doi.org/10.5281/zenodo.6790736

Trucks passively remained in idle or sounded a subtle beep sound on the in-cab display to warn operators. Fixed lanes into the crusher remove the risk of striking the structure. The repetitive nature of reversing a truck was removed; however, it was replaced with remote operations occasionally overriding the system manually.

Table 3. Manual truck hazards associated with incidents

Hazard Type	Description	Associated with incident (#)	(%)	Transformation [b]
Manual truck hazards associated with incidents (removed or transformed hazards)				
Driver awareness	Driver unaware of situation	140	24.73%	R
Load unit interaction	Heavily loaded or struck by excavator	107	18.90%	T
Truck ergonomics	Seating and steering arrangement	88	15.45%	R
Haul interaction	Truck interaction with haulage class	78	13.78%	T
Road conditions	Rough, wet or slippery conditions	32	5.65%	T
Plant interaction	Structure contact can cause truck damage	25	4.41%	T
Boarding ramp interaction	Ramp used to swap out truck drivers	20	3.53%	R
Heavy loading	Large rocks dropped from height	18	3.18%	R
Light vehicle interaction	Truck interacting with small vehicles	15	2.65%	T
Diesel fumes	Fumes airborne in truck cab	9	1.50%	R
Mechanical breakdown	Base truck mechanical problem	6	1.06%	T
Road maintenance interaction	Interaction with equipment working on road	5	0.88%	T
Changing crush lights	Crusher lights changing from red or green	4	0.70%	T
Refuelling hose	Contacting or leaving hose attached	3	0.53%	T
Clean-up machine interaction	Clean-up machine moving around in loading area	3	0.53%	T
Oversize material	Large rocks block crusher or damage truck	3	0.53%	T
Material logging	Material is identified incorrectly (ore vs waste)	2	0.35%	T
Open edge	Exposed height with windrow protection	2	0.35%	R
Access and egress	Climbing up and down truck access ladders	1	0.17%	T
Airborne dust	Dust inside truck cabin	1	0.17%	T
Procedure knowledge	Driver unsure of traffic procedure	1	0.17%	T
Falling material	Large rocks fall out of the tray onto the road	1	0.17%	T
Tyre failure	Ruptured tyres from use or heat	1	0.17%	R
Machine simulation	Simulation working environment	1	0.17%	R

[b] **Key: R = Removed, T = Transformed**

Boarding ramp interactions had been removed, howbeit trucks continued to be refuelled and inspected. Therefore, a person was still required to interact with the truck. Although exposing drivers to diesel fumes in the cab were eliminated. Predefined lanes allowed driverless trucks to be more accurate in parking beside the fuel bay. Injuries continued to be sustained during truck refuelling. Equipment breakdowns had also remained, however technology-based functions were created. Technology had introduced communication loses. Without a network, driverless trucks will immediately stop. This had driven the increase in lane breaches in driverless operations. Where trucks would previously breach AMA's, light vehicles became the centre point. The risk simply shifted to another proponent, hence the increase in zone locking hazards. Material that was dumped into a loading or dumping area was previously not a hazard. However, since the technology had limited vision of dumped dirt, the material must be surveyed into the virtual mine model to determine the boundary. Similarly, non-site aware vehicles cannot be seen in the virtual system, therefore the trucks had to rely upon LiDAR and RADAR technology to detect objects.

Table 4. Driverless truck hazards associated with incidents

Hazard Type	Description	Associated with incident (#)	(%)	Transformation [c]
Driverless truck hazards associated with incidents (new or transformed hazards)				
Road condition	Wet and slippery road conditions	116	26.62%	T
Clean-up machine interaction	Clean-up machine moving around in loading area	66	15.28%	T
Road obstacle	Truck detects windrow or rock	47	10.88%	N
Communication loss	Truck loses communications	38	8.65%	N
Haul road interaction	Truck interacting with haulage class equipment on road	29	6.71%	T
Load unit interaction	Truck being loaded heavily or struck by excavator	27	6.25%	T
Road maintenance interaction	Truck interacts with equipment working on road	22	5.09%	T
Operator awareness	Manual equipment unaware of truck presents	20	4.63%	T
Non-surveyed material	Material not surveyed into mine model	7	1.62%	N
Zone locking	Virtual zones not in place or applied properly	6	1.39%	N
Speed zones	Zones triggering significant truck speed decrease	6	1.39%	N
Non-site aware equipment	Equipment loses escort and does not have a predicted path	6	1.39%	N
Light vehicle interaction	Truck interacting with small vehicles	5	1.16%	N
Technology breakdown	Technology hardware breakdowns	5	1.16%	N
Full dump spot	Dump location already has material	4	0.93%	N
Stationary truck	Truck stationary on haul road	4	0.93%	N
Icon spin	Icon in virtual system flips to cause truck reaction	3	0.69%	N
Truck assignments	Truck loses assignment or lifts tray in loading bay	3	0.69%	N
Tyre separation	Tyre has separated from rim	2	0.46%	T
Single lane access	Virtual system moves trucks into oncoming lane	2	0.46%	T
Machine bubble	Virtual safety mechanism causing trucks to brake instantly	2	0.46%	N

Table 4 (cont). Driverless truck hazards associated with incidents

Hazard Type	Description	Associated with incident (#)	(%)	Transformation [c]
Material logging	Material type in truck does not match the system	2	0.46%	T
Mechanical breakdown	Base truck mechanical problem	2	0.46%	T
Refuel hose	Lifting refuel hose resulting in injury	1	0.23%	T
Survey mismatch	Virtual mine planned on wrong survey	1	0.23%	N
Changing crusher lights	Lights changing from red or green	1	0.23%	T
Full dump	Truck tips on full dump and material reels over windrow	1	0.23%	T
Fixed plant interaction	Truck recovered and manually tipped contacting crusher	1	0.23%	T
Spot point behind material	Tipping location placed over edges	1	0.23%	N
Oversize material	Large rocks block crusher or damage truck	1	0.23%	T
Rotating technology	Rotating LiDAR system potentially contacting technician	1	0.33%	N

[c] **Key: N = New, T = Transformed**

Matching the virtual world to the physical world has never been more important. Mining equipment could operate if manual fleet management system was inaccurate. However, in driverless systems, the risk is that trucks can reverse over physical objects once cleared. Even open edge risks to truck drivers has been taken away, it is been replaced with virtual dump locations behind windrows. This has the potential for trucks to reverse over windrows to find the location. However, what is the real risk though? There is no one in the truck? The point here, is that it's not the consequence in isolation, it's the systematic breakdown between human and machine. If the breakdown was connected to another situation, it is imaginable the implications that could emerge.

4. DISCUSSION

The analysis of driverless truck incidents offers some remarkable insights. Over the four-year transition period from manual to driverless control, the technology revolutionised the mine's risk profile. Although the value proposition for automation highlights a direct contribution to safety, the emergence of new hazards and risks remain. It appears that the WA Mining Industry is yet to fully understand the safety risks that driverless technology can introduce. Since the occurrence of a number of unconventional situations (Department of Mines and Petroleum, 2014), there are signs that the industry is starting to rethink how it approaches the expansion of driverless technology. This empirical research will enable the industry to improve their safety systems and leverage the lessons from this mine site.

The original assumption was that the replacement of drivers would eliminate the safety risks of truck driving. Removing the driver from behind the wheel gave the impression that technology took care of concentration lapses and fatigue-related events. This may have been the case, as driver awareness was found to be the most predominant hazard in manual operations. At the same time, however, as the site removed one conventional hazard, technology was simply introducing another. Shifting the most common hazard from driver awareness to road conditions. Therefore, the allocation of driving functions to a machine did not underpin the popular notion on safety. Without truck drivers behind the

https://doi.org/10.5281/zenodo.6790736

wheel, the mine site did however, achieve a reduction in haul truck incidents. Those incidents were also less frequent given the hours driven by both operations. Personal injuries in operations were almost non-existent, however the three injuries highlight how humans still interact with haul trucks in an operational context.

The transition saw a frequency reduction in haul truck incidents through an uplift in operating hours and reduction in incidents. The uplift was due to a natural expansion of the operation, while the reduction in incidents were realised through removing exposure and engineering elements of the haulage process. For example, automation removed exposure to vibration, sudden seat jolts and tray impacts. The permission-based control system coordinated truck interactions, increased travel lane accuracy and removed the need for associated infrastructure. Coordinating truck movement removed priority rules breaches and traffic management non-compliances. Specific travel paths avoided material contact, refuel hose damage and reversing into the crusher when tipping. All of which, made significant contributions to improving the mine site's safety performance. However, as conventional incidents were being removed, technology was in the process of exploiting residual risks and cultivating some of its own.

The introduction of unconventional incidents should be addressed with caution. Particularly in how they evolved and what appeared to be 'normal operations'. It was not a simple broken part; it was a complex human-machine interaction trying to achieve a goal: moving dirt. Technical limitations of driverless technology saw support roles locally adapt to keep the wheels turning. This was evident in the application of speed zones, road obstacles clearances and truck reassignments. Design parameters had neatly threaded humans along the fringes, creating a system that leveraged human redundancy to overcome non-design situations. Engineering capability coupled with residual tasks created a new system of work. A system that only expected what had been engineered. Human tasks were therefore filling in the gaps and learning through practice. Learning that driverless trucks needed speed zones in wet weather, clearance to proceed passed obstacles and new assignments when instructions were irrelevant. As a consequence, the risk profile extended beyond functional models and failure modes. It was a complex arrangement between driverless capability, residual work processes and the frontline joining the dots.

5. CONCLUSIONS

Despite the original assumption that safety risks could be eliminated through haul truck automation, this research highlights that the technology is not there yet. It is evident through the emergence of a new risk profile that was explored in this study. The risk profile is considered new when comparing the hazards and risks of a manual truck operation. Hazards were reflected in the incidents involving driverless trucks, which were unique to automated operations, due to novel pathways and situations that emerged through its introduction. This pinpoints the significance of identifying the safety risks when introducing driverless technology into a mining operation.

Significant progress has been made on removing human exposure to high-risk tasks. Automation was successful in reducing injuries to frontline personnel and coordinating the interactions between haul trucks. This highlights the value proposition of haul truck automation to the mining industry. It must be noted, however, that the industry cannot become complacent. Results of this study clearly show mining companies must truly understand the capabilities of the system they are using. Improving their user knowledge in not just how to work automation, but truly understanding how driverless trucks work. This will allow them to work more closely with the system and improve the transparency between human and machine.

https://doi.org/10.5281/zenodo.6790736

Based on the results of this analysis, it is recommended that WA Mining Industry, in particular, review their relevant Guidance Notes and Codes of Practices to reflect the hazards and risks that were outlined in this study. Modern innovation in safety practices need to be implemented to assist mining companies to thrive in this digital revolution. The automation of haul trucks is just one example, however the principles on human-machine collaboration can applied more broadly. An example would be explaining the importance of matching the physical mine to the virtual model. There are necessary steps in physical verifying digital models before automated equipment is clear to proceed. Developing new work practices can allow mining companies to redesign their safe systems for this next phase.

This study was based on the haul truck incidents that occurred on a mine site in WA. The fact that it was only conducted on a single mine site, with one product, is a limiting factor. There are increasing number of automated systems working across Australia. Despite incidents being an indication of possible breakdowns in the system, it may not have recorded all breakdowns that can result in an incident. In addition, the incident descriptions were interpreted to the best of the researchers' knowledge. As a consequence, incidents could have been grouped or labelled different to reflect the data. Moreover, not every haul truck incident may have been reported. Nonetheless, there is large sample size to allow the research to draw conclusions, with each incident and hazard type that were used to inform the study's findings.

REFERENCES

ADVI Hub (Producer). (2016, June 27). Applying Automation in the Mining Sector to Environments in the Public Interface. [Video file] https://www.youtube.com/watch?v=dDAQoH1nlNU

BHP. (2019). *Financial results for the half year ended 31 December 2018. Investor and analyst briefing speech.* https://www.bhp.com/-/media/documents/media/reports-and-presentations/2019/190219_bhpresultsforthehalfyearended31december2018_investorandanalystbriefingspeech.pdf?la=en

BHP blames heavy rains for autonomous trucks crash. (March, 2019). https://www.mining.com/bhp-blames-heavy-rains-autonomous-trucks-crash/

Dekker, S. W. A., & Woods, D. D. (2002). MABA-MABA or abracadabra? Progress on human–automation co-ordination. *Cognition, Technology & Work, 4*(4), 240-244. doi:10.1007/s101110200022

Department of Mines and Petroleum. (2014). *Mines Safety Bulletin No. 110*. Retrieved from https://www.dmp.wa.gov.au/Documents/Safety/SRS-Publications-Mining_and_Explorations-Safety_Bulletin_114.pdf

Department of Mines and Petroleum. (2015a). *Safe mobile autonomous mining in Western Australia*. http://www.dmp.wa.gov.au/Documents/Safety/MSH_COP_SafeMobileAutonomousMiningWA.pdf

Department of Mines and Petroleum. (2015b). *Signficant Incident Report No.226*. http://www.dmp.wa.gov.au/Documents/Safety MS_SIR_226_Collision_between_an_autonomous_haul_truck_and_manned_water_cart.pdf

Fortescue Metals Group auto haul truck crash Christmas Creek 'no failure' of system. (February, 2019). https://thewest.com.au/business/mining/fortescue-metals-group-auto-haul-truck-crash-christmas-creek-no-failure-of-system-ng-b881104957z

Fortescue Metals Group Limited. (2019). *June 2019 Quarterly Production Report*. https://www.fmgl.com.au/docs/default-source/announcements/1950659.pdf?sfvrsn=2817c93_7

Gray, D. (2019). No one behind the wheel: The new workforce driving Australia's mines. https://www.smh.com.au/business/companies/no-one-behind-the-wheel-the-new-workforce-driving-australia-s-mines-20190411-p51dd2.html

Hamada, T., & Saito, S. (2018). Autonomous Haulage System for Mining Rationalization. *Hitachi Review, 67*(1), 87-92. http://www.hitachi.com/rev/archive/2018/r2018_01/pdf/P087-092_R1a07.pdf

HWE Mining to face retrial over death of Adam Sargeant at Yandi mine. (2014). https://www.watoday.com.au/national/western-australia/hwe-mining-to-face-retrial-over-death-of-adam-sargeant-at-yandi-mine-20140123-31bdt.html

Jacques, J. S. (2019). *Rio Tinto 2019 half year results*. https://www.riotinto.com/documents/190801_Rio_Tinto_2019_half_year_results_script.pdf

Lee, J. D., & Morgan, J. (1994). *Identifying Clumsy Automation at the Macro Level: Development of a Tool to Estimate Ship Staffing Requirements.* Paper presented at the Human Factors and Ergonomics Society 38th Annual Meeting.

Panetta, K. (2019, August 29). 5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies, 2019. https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/

Woods, D. D. (2016). The Risks of Autonomy: Doyle's Catch. *Journal of Cognitive Engineering and Decision Making, 10*(2), 131-133. doi:10.1177/1555343416653562

AUTHORS

Dr. Todd Pascoe, MOccMedHlth&SaF, is a Business Improvement Specialist in the Western Australian Mining Industry. Todd has worked in the Western Australian Mining Industry for over 10 years in specialised roles across Health and Safety, Mining Production and Business Improvement. Todd has extensive operational experience in the deployment and day-to-day running of an autonomous haulage system, including the development of risk assessments, health and safety systems and operational efficiencies.

Dr. Shirley McGough, RN, MHN, Dip App Sc, BSc (Nursing), PG(Nurs), MNurs, PhD, Senior Fellow, Higher Education Academy. Shirley currently works at Curtin University and teaches mental health, behavioural and biosciences, conducts research and evidenced based practice. Shirley has extensive clinical and research experience in mental health and wellbeing, with substantial educational and leadership experience in the University sector.

Dr. Janis Jansz, RN, RM., Dip. Tch, BSc. Grad. Dip. OHS, MPH, PhD, FSIA is an Associate Professor in Occupational Health, Safety and Environmental Health in the Western Australian School of Mines: Minerals, Energy and Chemical Engineering at Curtin University in Western Australia and is a Professor at the Xi'an University of Science and Technology, China. She also works for the Healthforce Group. Janis is the Director of the World Safety Organization National Office for Australia and Vice President of the Occupational Health Society of Australia. She has been awarded Life Membership of the Australian Institute of Health and Safety for many years of work improving, teaching and conducting research to advance occupational safety and health practices and for taking a leadership role the safety and health profession.

World Safety Journal

A peer-reviewed journal,
published by the World Safety Organization

Journal Homepage:
https://worldsafety.org/wso-world-safety-journal/

An analysis of investigation reports into heavy vehicle and train crashes in Australia suggests anomalies in investigations and reporting

Ivan Cikara[1*], Geoff Dell[2], Aldo Raineri[1], and Shevaun Dell[3]

[1] *Central Queensland University*

[2] *Central Queensland University and VŠB-Technical University of Ostrava*

[3] *Independent Researcher*

KEYWORDS

Heavy Vehicle
Train
Investigation
Level Crossing
Crash
Driver

ABSTRACT

The Australian Transport Safety Bureau (ATSB) is Australia's national transport safety investigator tasked with independently investigating, analysing and reporting on transport safety matters. Currently, the ATSB does not have a mandate to investigate the heavy vehicle transport industry, being confined to the investigation of incidents and accidents in the aviation, maritime and rail domains. However, it has been recommended that the ATSB should take over investigation of heavy vehicle crashes. This may not be the panacea it promises to be as the ATSB may not be well placed to undertake heavy vehicle crash investigations thoroughly. To be successful, not only will the ATSB need to have a mandate to investigate heavy vehicle crashes but will also need to undertake systemic investigations that go beyond findings of human error instead of fully investigating the reasons why the human error occurred.

This study thematically analysed the publicly available investigation reports completed by the ATSB of collisions between heavy vehicles and trains at level crossings that occurred between 2000 to 2019. The analysis identified that the investigations were varied in complexity, content and information and found there was a focus on heavy vehicle driver behaviour resulting in human error and limited examination of the deficiencies at the organizational level and other underlying factors that could influence heavy vehicle driver behaviour. The study argues that to prevent a recurrence of a crash it is critical to identify and analyse all the underlying causal factors of a crash. When driver behaviour is identified as a causal factor it just may be the end result of a causal sequence that was first triggered by a foundation of organizational deficiencies likely to have commenced long before the crash occurred.

.

Corresponding author: ivan.cikara@cqumail.com

https://doi.org/10.5281/zenodo.6790767

1. INTRODUCTION

Level crossing crashes between road vehicles and trains are a significant problem in Australia. The Office of the National Rail Safety Regulator (ONRSR, 2021) has reported that between January 2016 and December 2018, there have been 91 collisions involving a road vehicle and a train at a level crossing - 24 collisions in 2016, 35 collisions in 2017, and in 2018 there were 32 collisions. Despite grade separation programs having reduced the number of level crossings in the major Australian cities, they are still prevalent, especially in rural areas. It is estimated that 23,000 level crossings still exist (ONRSR, 2021) of which there are approximately 8900 public railway and pedestrian level crossings.

Twenty-one per cent (21%) are actively controlled, that is that they have boom gates and or flashing lights to alert road users when a train is coming. The other seventy-nine per cent (79%) of level crossings are passively controlled, that is they have either a stop or give way sign, but no active means of alerting the road user to the presence of an approaching train (ARTC, 2016).

Heavy vehicle crashes at level crossings are the most severe of all road crashes in terms of deaths, injuries and financial losses (Davey et al., 2008). A heavy vehicle in Australia is defined in s6 of the Heavy Vehicle National Law (2012) and s3 of the Road Traffic (Vehicles) Act (2014) - Western Australia, as a vehicle that has a gross vehicle mass or aggregate trailer mass of more than 4.5 tonnes. The gross vehicle mass of a heavy vehicle is the maximum it can weigh when fully loaded. Heavy vehicles include semi-trailers, road trains, buses, mobile cranes and other special purpose vehicles, freight trucks and vehicle carriers. In the United States of America heavy vehicles are described in their Transport Policy 2021 as heavy-duty vehicles, have a gross vehicle weight rating of 8500 pounds, which is equal to 3.87 tonnes equivalent, and in Canada a gross vehicle mass of 3.856 tonnes (Transport Policy, 2021).

Heavy vehicle crashes, especially those involving fatalities, are currently only investigated by State and Territory police services, in order to identify liability with a view to prosecution under road traffic legislation. Where a fatality is involved, police also conduct investigations on behalf of State Coroners (Productivity Commission, 2020), who are required under relevant legislation to determine the cause of death. In addition, since a heavy vehicle falls within the definition of a workplace under Commonwealth, State and Territory work health and safety legislation, the relevant WorkSafe authority also has a mandate to investigate heavy vehicle crashes with a view to determining liability under work health and safety laws. However, WorkSafe authorities rarely exercise their legislative powers to investigate heavy vehicle crashes. Additionally, if the crash were to occur on a mine site, the relevant State or Territory mines regulator also has a legislative mandate to investigate the crash. Where a crash occurs at a level crossing the Office of the National Rail Safety Regulator (ONRSR) and the Australian Transport Safety Bureau (ATSB) may investigate, however where they do investigate, they only focus on the rail aspects of the crash.

In addition to these State and Territory regulatory and investigative agencies, the Australian Transport Safety Bureau (ATSB) has a mandate to investigate incidents in the aviation, maritime and rail domains. However, the ATSB is Australia's national transport safety investigator tasked with independently investigating, analysing and reporting on transport safety matters (ATSB, 2019a). The ATSB does not investigate the heavy vehicle transport industry. Consequently, any data regarding level crossing crashes between trains and heavy vehicles stems from ATSB rail focused investigations. Based on the publicly available investigation reports, it appears that not all of the crashes included in the ONRSR data mentioned above were investigated by the ATSB.

https://doi.org/10.5281/zenodo.6790767

Because the scope and focus of how investigations are conducted is influenced by organisational, political and societal contexts (Dien et al., 2007; Accou & Reniers, 2019; Hutchings, 2017), these overlapping regulatory and investigative jurisdictions result in independent, separate, parallel and sometimes fragmented and conflicting investigations being conducted. Each agency has its own investigative methodology and purpose and there is little if any collaboration and cooperation between agencies. Even the end result can be significantly different. Most, if not all Investigations are conducted to identify breaches of governing legislation and evidence is gathered with a view to determining failure to meet regulatory provisions (Productivity Commission, 2020). In this regard, proximal causal factors are the focus of these investigations. On the other hand, the ATSB does not prosecute, but conducts a "no blame, no liability investigation' for the purposes of engaging industry and identifying lessons to be learned from the failure (ATSB, 2019b).

The evidence suggests that the current arrangements are less than optimal. The Labour Council of New South Wales (2001), for example, concluded that the risks involved at level crossings were far more serious than the contemporary reports of the investigations into the crashes would suggest. Given that heavy vehicle traffic on Australian roads is expected to double within 10 years (IBIS, 2017), there is a need to assure the systemic causes of level crossing crashes are understood and effective mitigators put in place. Therefore, there is a need to improve understanding of the causes of level crossing crashes, in particular the effectiveness, vulnerabilities and limitations in the components of the road and rail systems intended to prevent level crossing crashes. Given the multiplicity of investigative agencies, with varying investigation purposes and methodologies, the Productivity Commission (2020) has recommended that the ATSB should take over investigation of heavy vehicle crashes. However, this may not be the panacea it promises to be as the ATSB may not be well placed to undertake heavy vehicle crash investigations thoroughly. To be successful, not only will the ATSB need to have a mandate to investigate heavy vehicle crashes, but in order to make a difference they will need to undertake systemic investigations that go beyond superficial causes like blaming the driver or simply classifying human factors, instead of fully investigating the reasons why human error occurred. A finding of human error ought to be the start of an investigation not the end (Leveson, 2011; Debrincat et al., 2013; Dell, 2015; Doecke, 2020; NOPSEMA, 2020).

This paper reviews the ATSB investigation of crashes involving heavy vehicles and trains at level crossings since this is the only context in which the ATSB has considered heavy vehicle involvement in crashes to date.

2. RESEARCH AIM

The aim of this study was to conduct a thematic analysis (Petticrew & Roberts, 2006; Timulak, 2009; Mytton et al., 2017) of crashes involving heavy vehicles and trains at level crossings for the purposes of identifying and examining whether common themes exist, what causal factors were identified and if systems investigations were conducted (Baysari et al., 2008).

3. RESEARCH DESIGN

This research comprised a thematic analysis of the total number of publicly available investigation reports published by the ATSB regarding heavy vehicles crashing with trains. Data was collected from each investigation report which identified the total number of contributing factors and supplementary causes mentioned in the reports. Where multiple contributing factors and supplementary causes were reported, all were included in the dataset.

A data extraction matrix was created to capture the information contained within the reports. This matrix included information such as crash type, type of level crossing i.e. active level crossing or passive level crossing, train driver drug and alcohol testing, fatigue, health, experience, risk taking, track speed, heavy vehicle description, vehicle defects, load descriptions, occupational factors, heavy vehicle driver familiarity, heavy vehicle driver risk taking, location, location design, heavy vehicle driver details i.e. age, years of experience, weather conditions, level crossing compliance, heavy vehicle driver health, fatigue, drug and alcohol testing.

3.1 Inclusion criteria

A search of ATSB investigation reports that were completed between 2000 to 2019, where a heavy vehicle was involved in a collision with a train was conducted within the 'Rail Safety Investigations' section of the ATSB website. This section is open and accessible to the public for general viewing and access. The analysis only considered those reports where a heavy vehicle was being driven at the time of impact. Crashes that involved heavy vehicles or buses that were abandoned on the rail track with no driver or passengers on board were not included in this analysis. Specifying particular locations and other factors were not required as this would have limited the search scope.

The search identified 251 records of rail investigations that were either active or completed. A review of each investigation title was then conducted to identify which investigation involved rolling stock and a heavy vehicle. This search captured 17 reports that met the search criteria. The executive summary of each report was then read to confirm that the investigation met the search criteria, and the crashes did in fact involve a collision between rollingstock that includes trains and locomotives and a heavy vehicle. The study population included all:

- Collisions involving fatalities, injuries or non-injuries.
- Types of trucks, so long as the heavy vehicle was equal to or greater than 4.5 tonnes gross vehicle mass, but not including buses.
- Vehicles whether owner operator or operated by employees working on behalf of a company.
- Types of level crossings.
- States of Australia and in any location within Australia.
- Types of trains and locomotives, whether they were freight trains, passenger trains, grain trains or ballast trains.
- Trains owned or operated by any private sector or government authority.

3.2 Limitations of the study

The study is limited by the data source being confined to the ATSB investigation reports which are publicly available. A search of the ATSB website was not able to find investigations of crashes involving trains and heavy vehicles occurring between 2008 and 2013. This does not suggest that investigations were not conducted during that period, simply that the investigation reports were not publicly available.

4. AUSTRALIAN TRANSPORT SAFETY BUREAU (ATSB)

4.1 Overview

Established by the Transport Safety Investigations Act 2003 (TSI Act, 2003), the ATSB investigations are conducted in accordance with the requirements of the Act with a focus on improving safety within the transport industry. The ATSB makes it clear that its function is not to apportion blame or liability in

https://doi.org/10.5281/zenodo.6790767

safety matters and does not investigate crashes for the purposes of administrative, regulatory, or criminal action (ATSB, 2019b).

In addition, it should be noted that each of the industries the ATSB focuses its investigations on are also regulated by a specific Regulator for that industry. For example, aviation is regulated by The Civil Aviation Safety Authority (CASA), rail is regulated by the Office of the National Rail Safety Regulator (ONRSR) and maritime is regulated by the Australian Maritime Safety Authority (AMSA). All three are national Regulators. The heavy vehicle transport industry is an anomaly. Although there is a Heavy Vehicle National Law and a Heavy Vehicle National Regulator, with a newly implemented investigative function, the Heavy Vehicle National Regulator is not a national body, and under the cooperative federal model which is the basis for this Law, it has no regulatory responsibility or oversight within Western Australia and the Northern Territory.

4.2 Investigation process in the ATSB

The ATSB reports that it receives more than 17 000 notifications of transport crashes and accidents each year (ATSB, 2019c). The ATSB directs its resources to those crashes and accidents with the greatest potential of identifying systemic issues in aviation, marine and rail transport (ATSB, 2019c) and conducts diverse different types of investigations according to the anticipated scope and scale of the work required to determine the underlying causes of a safety occurrence (ATSB, 2019d). All investigations, however, despite their length, complexity or classification are conducted under the auspices of the *Transport Safety Investigations Act 2003* (TSI Act, 2003), with the principle aim of each investigation being to identify systemic safety issues that reveal the underlying causes of the accident.

4.3 Rail investigations

The ATSB selectively investigates rail incidents and steers investigative resources and capabilities towards those incidents considered most likely to enhance rail safety. The ATSB openly states that because many of the incidents that occur on the rail network are repetitive in nature, there may not be justification to investigate these incidents in detail, due to the limited resources of the ATSB (ATSB, 2019e). The aim of the ATSB investigation into rail incidents, as it is with all incidents, is to seek to determine the circumstances, identify any safety issues and encourage relevant safety actions. The primary focus is to prevent a reoccurrence of the incidents rather than to assign blame or liability.

5. RESULT OF THE THEMATIC ANALYSIS

5.1 Identification of contributing factors

The 17 investigation reports contained 46 documented contributing factors. The number of contributing factors in each report is identified as follows:

- 14 reports contained between 1-5 contributing factors.
- One report contained between 6-10 contributing factors.
- 16 reports attributed contributing factors to the driver.
- There were two reports that did not specifically identify a contributing factor. These reports contained a summary of events of findings to describe what had occurred.

https://doi.org/10.5281/zenodo.6790767

A breakdown of these is contained in Table 1.

Table 1. The numbers of contributing factors that appeared in each investigation report.

The number of contributing factors in the investigation report	Number of reports
1-5	14
6-10	1
11-15	Nil
16 +	Nil
Other	2

An analysis of these contributing factors found multiple elements within a number of factors. Accordingly, each contributing factor was analysed to identify how many contributing factors were actually contained within the one. For example, one contributing factor identified in a report stated: *'It is likely the actions of the driver not stopping may have been influenced by familiarity with the crossing and the expectation that a train would not be present'*. When breaking this contributing factor down there were two contributing factors identified: 1. *Familiarity with the crossing* and 2. *Expectation a train would not be present*.

In another example the contributing factor stated: *'It is likely that a phenomenon known as 'intentional blindness' contributed to the truck driver's failure to see the approaching train, even though it is likely that he looked in that direction. The road junction, road traffic, low train conspicuity and a low expectation of seeing a train probably combined to mistakenly filter attention away from the importance of looking for a train'*. When breaking this down there are four contributing factors: 1. '*Inattentional blindness'* 2. *'The road junction, road traffic'* 3. '*Low train conspicuity*' and 4. '*Low expectation of seeing a train'*.

In yet another example the contributing factor stated: '*It is probable that the truck driver's familiarity with the crossing, low expectation of encountering a train and possible increased propensity to take risks were personal characteristics/factors that may have led to him failing to stop at the crossing and thus contributed to the collision'*. In this contributing factor there are four contributing factors: 1. '*Driver's familiarity with the crossing'*, 2. '*Low expectation of encountering a train'*, 3. '*Possible increased propensity to take risks',* 4. '*Personal characteristics/factors that may have led to him failing to stop at the crossing'*.

By doing so, this study suggests there are a total of 70 contributing factors rather than the 46 reported in the ATSB investigation reports. These 70 contributing factors were then attributed to a number of themes. These themes were developed by the authors from a detailed consideration of the multiplicity of contributing factors identified in the investigation reports and a teasing out of individual elements considered in each investigation. Table 2 below identifies these 16 themes.

https://doi.org/10.5281/zenodo.6790767

Table 2. Themes identified from the contributing factors

Themes from contributing factors	Number	%
Error attributed to the heavy vehicle driver	27	38.5
Angle of the road to the level crossing	7	10
Low expectation of seeing a train	6	8.5
Design of the heavy vehicle cabin	5	7.1
Train – Safety Management System	4	5.7
Government	4	5.7
Road design	3	4.3
Sighting distance affected due to vegetation	3	4.3
Familiarity	2	2.8
Traffic conditions	2	2.8
Heavy vehicle driver scheduling	1	1.4
Not familiar with the area	1	1.4
Heavy vehicle driver workloads	1	1.4
Lack of enforcement	1	1.4
Heavy vehicle driver did not hear train	1	1.4
Contributing factor not relevant	1	1.4
Total	**70**	

5.2 The 'supplementary causes' identified in the reports

Each report outlined a number of supplementary causes. These are additional causes which are not considered to be as significant as contributing factors. Each supplementary cause was individually analysed to identify which part of the socio-technical system it belonged to. The supplementary causes were then broken down into themes which were then placed into the specific socio-technical system categories identified in Table 3.

The study identified 76 supplementary causes, of which 44 attributed blame to the heavy vehicle driver, 11 to the road design (that included acute angle of the road to the level crossing, and the design of the road junction), five to the design of the heavy vehicle cabin, five to Government/Local Government, four to company, five to environment and one to enforcement. These are set out in Table 3.

https://doi.org/10.5281/zenodo.6790767

Table 3. Socio-technical system categories with a breakdown of the number of specific themes

System	Total	Supplementary causes
Government	n=5	Maintenance of environment (Shrubs) (n=1); Inadequate interface with rail company (n=1); Sighting distance (n=2); Risk controls (n=1)
Regulator/ Enforcement	n=1	Failure to enforce compliance (n=1)
Company	n=4	Changes to Safety Management System (SMS) (n=1); Failing to address level crossing (LX) sighting distance (n=1); Inadequate interface with local government (n=1); Inadequate risk controls (n=1)
Driver	n=44	Fail to give way or stop (n=12); Not driving to the conditions (n=2); Speed (n=2); Time pressures (n=1); Familiarity (n=3); Site unfamiliarity (n=1); Behaviour (n=1); Inattentional blindness (n=1); Not driving with caution (n=2); Failure to hear horn (n=1); Increased risk (n=1); Low or no expectation of train (n=5); Focused on other driving (i.e., negotiating curves (n=1); Inattention/preoccupied /distracted/unaware (n=7); Did not look or perceive flashing lights (n=1); Insufficient time for the train driver to stop the train before colliding with the truck (n=1); The semi-trailer driver probably did not hear the locomotive horn, if at all (n=1)
Vehicle	n=6	Cabin design (n=5); Low train visibility (n=1)
Road design	n=11	Angle of the road to the level crossing (n=8); Road junction (n=1); Traffic volume (n=1); Road Layout (n=1)
Environment	n=5	Reduced visibility due to shrubs/trees (n=3); Visibility was reduced by heavy fog (n=1); Reduced visibility due to the sun (n=1)

5.3 Analysis of results

This section outlines the systematic analysis of the details contained in the investigation reports taking into account the matters that were discussed in the report along with the contributing factors and supplementary causes. The investigation reports were spread out between the years 2000 to 2019. The analysis captured one investigation from 2002, five investigations from 2006, three from 2007, one from 2008, two from 2013, one from 2014, one from 2015, one from 2016 and two from 2017.

a) *Where crashes occurred*

All 17 crashes occurred in rural areas and at public level crossings. Fourteen crashes occurred at a passive level crossings. Six crashes occurred on bitumen roads and eight occurred on gravel roads. Three crashes occurred at an active level crossing with two occurring on bitumen roads and one on a gravel road.

In relation to contributory factors there were three crashes that occurred after the heavy vehicle driver negotiated or was negotiating a bend, two crashes occurred at a level crossing being actively controlled and one crash occurred at a passively controlled level crossing. This was also combined with a low expectation of encountering a train and a failure to stop or giveaway at the level crossing controls resulting in a crash.

Five of the investigations noted that vegetation alongside and surrounding the level crossing likely impeded the heavy vehicle drivers sighting distance and visibility of the train. In another five of the investigations, it was suggested the design/pillar of the heavy vehicle's cabin impaired or obstructed the driver's visibility and contributed to the likely-hood the driver did not see the approaching train. However, one investigation report did not include the cabin design as a contributory factor even though it was identified and discussed within the investigation report.

In eight of the crashes, it was identified there was an acute angle of the road to the level crossing that may have affected the heavy vehicle drivers sighting distance of the train at the level crossing and in five crashes there were instances where the level crossing controls and warning markings were not compliant with the relevant Australian Standards.

b) *Environment*

The weather conditions were described in all reports as being either fine, dry, sunny, clear, overcast or dusk.

c) *Train driver*

In 13 reports drug and alcohol testing was identified as being conducted, all with negative results. Fatigue was investigated and identified as not being a contributing factor. Three reports did not identify if drug and alcohol testing was conducted or if fatigue was investigated. Fourteen reports included train driver health, experience and risk taking; however, three reports did not identify these factors and three of the reports did not include any of the above five factors above.

d) *Train speeds*

Train impact/travelling speeds were identified in 12 of the crashes ranging from 10 kph to 112 kph with a median impact speed being 85.25 kph. Impact speeds were not identified in five of the reports.

e) *Heavy vehicle (i.e., sizes and types of heavy vehicles, weights)*

Vehicle type and configuration were identified in all crashes and varied broadly. The configurations included road trains, tipper trucks, tandem axle, road trains and flat top rigid trucks conveying a vastly diverse number of products such as cement, sewerage, bales of hay, storage container and gypsum.

The gross vehicle mass (GVM) of the vehicle was documented in 13 of the reports. Ten of the GVM's were in excess of 42.5 tonne with one as heavy as 62.5 tonne and another as heavy as 80 tonnes. Of the lesser GVMs there were two at 26 and 26.5 tonne and one at 4.5 tonne. Three others were not described.

The vehicle loads were identified for the heavy vehicles in six of the 17 crashes. This is an important factor as the size and mass of a heavy vehicle can impact upon the heavy vehicle's ability to accelerate, brake, manoeuvre and affect stability on a road. The mass of a vehicle can also impact upon a driver's decision as to whether they have sufficient time to brake or to accelerate (Davey et al., 2008).

In one crash it was identified the vehicle was not licenced and in two crashes the vehicle was not fit for purpose and possibly defective. The reports did not identify the system process that permitted the vehicles to be used when unlicensed or not suitable for the task.

f) Heavy vehicle driver: Owner operator or employee

There was a total of 10 employed heavy vehicle drivers, five owner operators and two investigation reports that did not identify if a driver was either employed or was an owner operator.

All heavy vehicle drivers were driving for the purposes of work. It was identified that in one crash a passenger was accompanying the heavy vehicle driver, while all other drivers were operating alone. Circumstance of employment were documented in 15 of the reports, while two reports did not identify if the drivers were either employed or owner operators.

g) Active or passive level crossing

Level crossings are controlled by either an active control or a passive control. There are significant differences between the two. For example, an actively controlled level crossing includes flashing lights, audible bells, stop signs and advanced warning signs whereas a passively controlled level crossing only includes a stop sign with accompanying signage at the location of the level crossing. This study identified that 14 level crossings were passively controlled and three were actively controlled.

h) Bitumen or gravel surface

The three active level crossings were located on bitumen sealed surfaces. Of the 14 passive level crossings eight were located on a gravel surface and six were located on a bitumen sealed surface.

i) Locations in Australia

The crashes were spread across Australia occurring in NSW (n=3), South Australia (n=4), Northern Territory (n=2), Victoria (n=6), Queensland (n=1), Western Australia (n=0), Tasmania (n=0).

https://doi.org/10.5281/zenodo.6790767

j) Heavy vehicle driver experience

All drivers were considered to be experienced. However, the number of years of experience was not identified in all reports. Driver competencies were not described. Information on driver training, driving to road rules, 39ehavior39ional training and assessment, defensive driving capability, route knowledge and fatigue management courses were not described in the reports.

k) Heavy vehicle driver local area knowledge/familiarity

A review of the investigation reports identified information in 15 reports that suggested the heavy vehicle driver was familiar with the area where the crash occurred. This familiarity was attributed to the driver:

- Having resided in the area,
- Growing up in the region,
- Having travelled along that route on numerous occasions,
- Working in the area, or
- Required to travel that route for work purposes.

This knowledge and familiarity extended into a number of years and even decades.

There was only one instance where the driver was not familiar with the area and was required to navigate around the site. Another report did not identify whether the driver was familiar with the area due to the investigations focus on other factors.

l) Month of year/day of week/time of day

Crashes occurred in each month of the year aside from January, April and June. Crashes varied by time of year and day of week. Most crashes occurred on weekdays (n=13) and four occurred on the weekend with most occurring on a Wednesday (n=5). Fifteen crashes occurred during day light hours. One crash occurred at 6.30 pm; however, the conditions were identified as being fine and clear.

m) Heavy vehicle driver health and fitness to drive

Driver health and medical conditions are a significant issue in work related crashes (Brodie et al., 2009; Robb et al., 2008). The review identified there were eight reports that did not assess driver fitness. Eight drivers were identified as being fit whereas one driver was identified as not being fit to operate a heavy vehicle. Known medical conditions were not identified in 16 of the reports.

In the one crash where it was identified the driver was not fit to operate a heavy vehicle, it was found that this was due to the driver having hearing loss. Additionally, the driver had not undergone a medical assessment to be declared fit to drive a heavy vehicle. This driver was an employee, and the report did not identify the due diligence process used to select the drivers or what process was used by the company to ensure the driver was medically fit to drive a heavy vehicle.

https://doi.org/10.5281/zenodo.6790767

n) Fatigue

In three of the crashes, it was identified there was the likelihood that driver fatigue may have been involved; however, the systemic causes or evidence to corroborate this claim was not examined in detail in the reports. The reports did not describe the fatigue management process used by the companies or owner operator involved to manage or identify the potential risk of fatigue.

o) Heavy vehicle driver demographics

All drivers were male. The median age of the driver, based on 10 reports that contained age related data, was 42.8 years, ranging from 28 – 57 years. There were seven reports that did not identify driver ages.

p) Level crossing compliance with Australian Standards

Five of the level crossings were not compliant with the relevant Australian Standards with either line markings missing, non-compliant road signage, significant overgrowth of vegetation affecting driver visibility, or stop sign assembly being removed. There were four reports where the level crossing compliance was not described. In a study conducted by Doecke et al. (2020) it was found that ‘road infrastructure treatments at intersections have the most potential to prevent crashes’ (p.40).

6. RESULTS OF REPORTS FOCUSING ON THE DRIVER

The 17 investigation reports were reviewed to identify how many reports attributed a contributing factor or supplementary cause to the driver of the heavy vehicle. The review found sixteen reports attributed driver error for the crash. These varied and included errors such as failing to stop at the stop sign, failing to give way, not driving with caution, not driving to the road conditions. Seven reports identified that the driver failed to drive without due care and attention.

7. DISCUSSION

The analysis of the ATSB reports identified that the investigations were varied in complexity, content and information. There was limited examination in the investigation reports of the heavy vehicle company organisational safety management system and risk management processes that managed driving risk. Crucial factors such as organisational management decisions that manage driver behaviours appeared to be overlooked and weaknesses in the organisational safety management systems did not appear to be analysed. Factors influencing behaviour at level crossings did not appear to be analysed and a systematic structured system thinking approach to investigating the crashes did not appear to be undertaken. This is consistent with findings by Dien et al. (2007) and Accou and Reniers (2019) who argued the scope of crash investigations is usually limited to the immediate causes and the accident sequence decision making process. Both authors highlighted the importance of looking extensively at organisational factors and their contribution to the crash. Commentators such as Read et al. (2017, 2021) and Salmon et al. (2013) identified that there are a number of factors across the level crossing system that interact to influence the risk at level crossings. Beale (2002) found that external hazards are difficult to manage or predict as they are outside the control of the rail operator which often lie at the root cause of crashes. This provides support for why it is important for investigations to focus attention on the safety management system failures of all those involved in the crash.

https://doi.org/10.5281/zenodo.6790767

The focus on driver behaviour is easier to investigate than investigating deficiencies at the organisational level. These deficiencies may include gaps in safety management systems, journey management planning, heavy vehicle driver fitness to drive, heavy vehicle maintenance, training, familiarity risk and whether the heavy vehicle companies recognised the hazards associated with active and passive level crossings, many of which can influence driver behaviour (Debrincat et al.,2013). In a study conducted by Debrincat et al. (2013) the authors argued that to prevent a recurrence of a crash it is critical to identify and analyse all the underlying causal factors of a crash and to do so can be difficult particularly when an investigation uncovers a myriad of causal factors. When driver behaviour is detected as being the causal factor it just may be the end chapter of a crash sequence that was first triggered by a foundation of organisational deficiencies likely to have commenced long before the crash occurred. For example, Leveson (2011) posited that an investigation should not stop when human error is identified as a deviation from a normal procedure. Rather, a more effective and relevant crash investigation model must be devised that shifts the focus away from explaining human error to explaining systems failures in organisational practices that shape the driver's behaviour. In a study conducted by Collet (2008) of fatal aeromedical helicopter crashes that attributed the cause of the crash to pilot error, the author suggested that an environment where an accident was waiting to happen may have been created by the organisational and operational systems and accepted practices. Human error was the end result of that sequence of organisational deficiencies (Debrincat et al., 2013).

The ATSB reports were limited in reporting other factors not relevant to the rail environment such as organisational requirements for heavy vehicle drivers to ensure compliance with State and Territory based regulatory road rules. Factors such as stopping at level crossing stop signs or flashing lights, what to do when approaching a passive level crossing with a stop sign etc, were not explored. Nor were matters such as regulatory compliance with speed limits, fatigue management and driver training investigated. Details such as the information on causal factors from other similar crashes, driver's fitness to drive assessments and vehicle maintenance records were not included within all reports. Additionally, information relevant to driver or journey management planning was not explored in any detail. For example, in one report it was identified the driver was concerned about 'arriving on time', but the reasons why were not explored in the report. Socio-technical system factors related to the heavy vehicle driver such as driver scheduling times and time pressures were not investigated to identify potential impacts upon the driver's behaviour and heavy vehicle company records were not analysed to identify any noncompliance with regulatory requirements. Without that level of investigation and analysis an opportunity to capture valuable information about the company's journey risk mitigation process is lost. Gou and Bellvigna-Ladoux (2003) argued that whilst there was evidence of risk taking by heavy vehicle drivers, the circumstances that influenced driver behaviours, such as organisational influences including scheduling, time pressures, poor management planning, inadequate journey management and risk management, were not taken into account. The opportunity to identify underlying causes as to why a crash has occurred are not discovered and lessons not learned (Cikara et al., 2020).

The findings of this study were consistent with the factors identified in research conducted by Davey et al. (2008) who examined the experiences and perceptions of heavy vehicle drivers and train drivers of dangers at railway level crossings. In that study a number of factors were identified that related to why crashes occurred at level crossings (Davey et al., 2008; Beanland et al., 2017). Davey et al. (2008) found that design, environment and angles of approach to a level crossing introduced a danger over and above a driver's control. The study also identified that the size, layout and level crossing designs often did not accommodate the specific needs of heavy vehicles. Level crossing configuration was also found to affect heavy vehicle driver visibility and effective heavy vehicle clearance. Davey et al. (2008) suggested that the two main causes of crashes between heavy vehicles and trains were as a result of the design of level crossings and heavy vehicle driver behavioural issues. This was identified in coronial

https://doi.org/10.5281/zenodo.6790767

findings of investigations into a level crossing fatality in Queensland, Australia (QLD 2008/392 & 2008/393, 2016) where the coroner stated:

> *Although there were a number of design features intended to control and mitigate the risk of collision, the physical layout and alignment of the road and rail corridor resulted in heavy reliance on road users detecting flashing lights, warning of a train approaching the crossing (p.18).*

A 2009 Australian House of Representatives Standing Committee on Infrastructure Transport, Regional Development & Local Government on Level Crossing Safety (AHRSLC, 2009) found that there was no single cause for all level crossing collisions and therefore no single solution. While the AHRSLC (2009) concluded that the most significant factor leading to a level crossing collision was driver behaviour, nonetheless there were other factors, such as vegetation obscuring the heavy vehicle driver's vision of the approaching train, that also contributed to level crossing collisions. In the same report the Australia Trucking Association (ATA) recommended that priority must be given to clearing vegetation that surrounds level crossing so that drivers have a clear line of sight. It was also identified that driver situational awareness of trains was also obstructed by the design of some level crossings caused by the level crossing not always being at right angles to the road.

In support, Gou and Bellvigna-Ladoux (2003) suggested that factors such as design and configuration of level crossings were also key factors not considered in investigations and also stressed that, level crossing design was often inadequate for heavy vehicles. This was supported in research by Davey et al. (2008) who reported that heavy vehicle drivers 'unanimously' complained that level crossings were often not designed in a manner which was user friendly to heavy vehicles.

Read et al. (2021) identified that most studies of level crossing events focused on drivers and that there were a large number of influencing factors demonstrating the complex nature of level crossing systems. However, the influencing factors were biased towards the lower levels of the socio-technical system, that is towards road user behaviours, vehicles and environment, whilst there were limited factors identified at the upper levels, i.e., Government, Regulatory and Company level. Read et al. (2021) argued that more research was needed to capture the systems thinking approach and better understanding of the behaviours in examining the interactions between level crossing system components.

8. AUSTRALIAN TRANSPORT SAFETY BUREAU (ATSB) INVESTIGATION METHODS

In 2019, the Australian Government's Auditor General completed a performance report into the efficacy of the ATSB's investigations of transport accidents and safety occurrences (Auditor General Report No 29, 2018-19). The Auditor General found that prior to 2018 the ATSB had not undertaken any benchmarking of its efficiency and performance in comparison to other relevant transport safety organisations. The report concluded that up until this time the ATSB were not efficient or effective in conducting investigations in a timely manner. The Auditor General also made comment on the criticism of the ATSB by the Australian Parliamentary Select Committee (2009) for the delay in its investigation into 'the 2009 ditching of an aircraft off Norfolk Island (nearly three years after the accident) plus the lack of detailed analysis and useful recommendations for avoiding future incidents and accidents' (Auditor General Report No 29 2018-19, p. 32). In addition, the Auditor General made four key recommendations – to improve timeliness, improve efficacy of resources, establish realistic time frames to conduct investigations, and benchmark investigations against other international agencies. Further, the Auditor General noted that the ATSB had in June 2017 introduced a formal investigation process that included:

> *…investigation planning to ensure appropriate scope and resources; safety factor reviews with managers and directors; and report review (for administrative and readability) by the Communications team (p. 30).*

The review of the ATSB investigation reports in this study identified inconsistencies in the level of detail and information captured and supports the findings of the Auditor General. For example, it was found that earlier investigations had identified contributing factors and supplementary causes which were not later identified in subsequent crashes. This suggests that previous investigations were not reviewed to inform subsequent investigations. Moreover, the contributing factors and supplementary causes were not considered and there was a lack of focus on the lessons that should be learned from previous similar crashes (Toft et al., 2012; Chosnek, 2020).

Whether a robust methodology has been introduced and adopted remains a moot point. The authors of this study were unable to obtain information on the investigative method used to investigate the crashes that were reviewed. The analysis of the investigation reports only identified two reports that were completed in 2017. This may be too small a sample size to adequately make any judgements about whether the investigation methodology noted by the Auditor General has, in fact, been adopted, or is working as meant. There is no doubt, however, that a defined investigative framework and methodology would assist greatly in the consistent collection and analysis of crash evidence (Salmon & Lenne, 2009).

9. CONCLUSION

The Australian Productivity Commission (2020) has recommended that the ATSB should take over investigation of heavy vehicle crashes. However, evidence from this study and comments in the Auditor General Report No 29 2018-19 by the Auditor General (2019) and the Australian Parliamentary Select Committee (2009) as well as the ATSB's own comments about its resources and capabilities (ATSB, 2019b) strongly suggest that this may not be the panacea it promises to be. The ATSB appears to be under-resourced currently to meet its mandate and will need to adopt a socio-technical system-wide approach to effectively investigate underlying causal factors in heavy vehicle crashes which operate in a domain that is distinctly different to aviation, rail and maritime.

In addition, a number of the contributory factors identified in the ATSB investigation reports focused on human factors alone. The investigation methodology used by the ATSB did not adopt a socio-technical systems approach and, therefore, the findings do not provide a complete account of all relevant causal factors. Identifying human factors should be where the investigation commences and digs deeply into the socio-technical system that influences the heavy vehicle driver. For this to occur, the ATSB will need to adopt an investigation methodology that applies a systematic examination of the socio-technical system. The analysis of the ATSB investigation reports in this study did not identify findings attributed to systemic causal factors leading back to the heavy vehicle companies. Sixteen of the 17 reports attributed blame for the crash on the heavy vehicle driver. The investigation reports did not capture a systemic analysis of causal factors that included the heavy vehicle transport system. Whilst this study identified several common themes and factors, such as the design of the heavy vehicle cabin as well as the angle of the road to the level crossing likely affecting driver visibility and sighting distance of the trains, these were only considered separately from each other and in isolation. The findings of previous crashes were not considered or used to inform the next investigation where valuable information may have been missed that could have assisted in forming suitable

https://doi.org/10.5281/zenodo.6790767

recommendations or reinforcing and supporting previous recommendations. When driver behaviour is detected as being the causal factor it just may be the end chapter of a crash sequence that was first triggered by a foundation of socio-technical deficiencies likely to have commenced long before the crash occurred. An investigation should not stop when human error is identified as a deviation from a normal procedure. Rather, a more effective and relevant crash investigation model must be devised that shifts the focus away from considering human error as the major cause to exploring systems failures in organisational practices that shape the driver's behaviour.

REFERENCES

Accou, B., & Reniers, G. (2019). Developing a method to improve safety management systems based on accident investigations. The SAfety FRactal Analysis. *Journal of Safety Science*, *115*, 285-293. DOI: https://doi.org/10.1016/j.ssci.2019.02.016.

Auditor General (2019). *Performance Report: Efficiency of the investigation of transport accidents and safety occurrences, no. 29, Australian Transport Safety Bureau*. Commonwealth of Australia, ISSN 1036-7632, ISBN 978-1-76033-432-1

Australian House of Representatives Standing Committee on Infrastructure Transport, Regional Development & Local Government on Level Crossing Safety (AHRSLC). (2009). Response to the House of Representatives Committee Report, level crossing safety: An update to the 2004 train illumination report, July 2009.

Australian Rail Track Corporation (2016). *Safety around level crossings; Level crossing safety*. https: www.artc.com.au/safety-around-level-crossings/www.artc.com.au/safety-around-level-crossings/.

Australian Transport Safety Bureau (ATSB). (2019a). *About the ATSB*. https://www.atsb.gov.au/about_atsb/.

Australian Transport Safety Bureau (ATSB). (2019b), *Agency overview*. https://www.atsb.gov.au/about_atsb/overview/objectives/.

Australian Transport Safety Bureau (ATSB). (2019c). *The investigation process.* https://www.atsb.gov.au/about_atsb/investigation-process/.

Australian Transport Safety Bureau (ATSB). (2019d). *Investigation level*. https://www.atsb.gov.au/about_atsb/investigation-process/investigation-level/.

Australian Transport Safety Bureau (ATSB). (2019e). *Does the ATSB investigate all rail accidents?* https://www.atsb.gov.au/publications/2014/rail-investigations-in-aust/.

Baysari, M.T., McIntosh, A.S., & Wilson, J.R. (2008). Understanding the human factors contribution to railway accidents and crash tests in Australia. *Journal of Accident Analysis and Prevention*, *40*, 1750-1757.

Beale, C.J. (2002). Recent railway industry accidents: Learning points for the process industries. *Journal of the Institute of Chemical Engineers*, *80*, part B, 25-32.

Beanland, V., Salmon, P.M., Filtness, A.J., Lenne, M.G., & Stanton, N.A. (2017). To stop or not to stop: Contrasting compliant and non-compliant driver behaviour at rural rail level crossings. *Journal of Accident Analysis and Prevention*, *108*, 209-219.

Brodie, L., Bugeja, L., & Ibrahim, J.E. (2009). Heavy vehicle driver fatalities: learning from fatal road crash investigations in Victoria. *Journal of Accident Analysis and Prevention*, *41*, 557-564.

Chosnek, J. (2020). Lessons learned: How to make them stick. *Journal of Process Safety Progress,* 1-4. DOI: https://doi.org/10.1002/prs.12198.

Cikara, I., Dell, G., Toft, Y., Dell, S., & Skrizovska, M. (2020). The need for enhanced heavy vehicle crash investigations: Beyond 'blame the driver'. *Transactions of the VSB - Technical University of Ostrava, Safety Engineering Series*, *15* (1), 60-72, (ISSN: 1805-3238). DOI: 10.35182/tses-2020-0007.

Davey, J., Wallace, A., Stenson, N., & Freeman, J. (2008). The experiences and perceptions of heavy vehicles drivers and train drivers of dangers at railway level crossings. *Journal of Accident Analysis and Prevention*, *40*(3), 1217-1222. DOI: https://doi.org/10.1016/j.aap.2008.01.005.

Debrincat, J., Cees, B., & Clark, G. (2013). Assessing organisational factors in aircraft accidents using a hybrid Reason and AcciMap model. *Journal of Engineering Failure*, *27*, 52-60. DOI: http://dx.doi.org/10.1016/j.engfailananl.2012.06.003.

Dell, G. (2015). Foreword, in Viner D, *Occupational risk control: Predicting and preventing the unwanted*, pp xv-xvi. *Gower Publishing*, Farnham.

Dien, Y., Dechy, N., & Guillaume, E. (2007). A*ccident investigation: From searching direct causes to finding in-depth causes. Problem of Analysis or/an of analyst?* Dechy, N., & Cojazzi, G.G.M. 33 ESReDA seminar, Nov 2007, Ispra, Italy, European Communities, Luxembourg, 16, 2007.

Doecke, S., Thompson, J., & Stokes, C. (2020). How do we prevent and mitigate crashes? Evidence from Australian at-scene in-depth crash investigations. *Journal of Safety Research*, *1*(2), 35-43.

Gou, M., & Bellvigna-Ladoux, O. (2003). *Impact of heavy vehicles on crossing safety. Development of an adapted design tool*. Transport Canada, Montreal, Canada.

Heavy Vehicle National Law 2012 (QLD).

House of Representatives Standing Committee on Infrastructure Transport, Regional Development & Local Government. (2009). *Level crossing safety, an update to the 2004 Train Illumination Report*, June 2009.

Hutchings, J. (2017). *Systematic factors in the investigation of South African railway occurrences*. PhD thesis, University of the Witwatersrand, Johannesburg.

IBISWorld Industry. (2017). September. *Road Freight Transport (Report 14610).* Australian market research report. https://www.ibisworld.com.au/industry-trends/market-research-reports/transport-postal-warehousing/road/road-freight-transport.html.

Labour Council of New South Wales. (2001). *Submission to the Staysafe Committee-Joint Standing Committee on Road Safety's Review of Railway level Crossings in New South Wales*. LCNSW, Sydney, Australia.

Leveson, N.G. (2011). Applying systems thinking to analyse and learn from events. *Journal of Safety Science*, *49*, 55-64.

Mytton, J., Goodenough, T., & Novak, C. (2017). Children and young peoples behaviour in accidental dwelling fires. A systematic review of the qualitative literature. *Journal of Safety Science*, *96*, 143-149. DOI: 10.1016/j.ssci.2017.03.019.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). (2020). *Human factors in accident investigations: Information paper*. Document number N-06300-IP1598 A442128.

Office National Rail Safety Regulator. (2021). *Level crossing safety*. https://ww.onrsr.com.au/about-onrsr/national-priorities/level-crossing-safety.

Petticrew, M., & Roberts, H. (2006). Chapter 6*: Synthesising evidence. In: Systematic review in the social sciences*, 164-190. London*:* Blackwell Publishing.

Productivity Commission. (2020). National Transport Regulatory Reform, Inquiry report: *Overview and recommendations, Australian Government, report no. 94*, Canberra. ISSN 1447-1329-1447-1337.

Queensland Coroners Court, Office of the State Coroner, Findings of Investigation: Non-inquest findings into the deaths of Michael Smithers and Richard Wetherell, 2008/392 & 2008/393, Cairns, Australia.

Read, G.J.M., Beanland, V., Lenne, M.G., Stanton, N.A., & Salmon P.M. (2017). *Integrating human factors methods and systems thinking for transport analysis and design.* Taylor & Francis. DOI: 10.1201/9781315589022

Read, G.J.M., Cox, J.A., Hulme, A., Naweed, A., & Salmon, P.M. (2021). What factors influence risk at rail level crossings? A systematic review and synthesis of findings using systems thinking. *Journal of Safety Science*, *138*, 1-13. DOI: https//doi.org/10.1016/j.ssci.2021.105207.

Road Traffic (Vehicles) Act 2014 (WA).

Robb, G., Sultana, S., Ameratunga, S., & Jackson, R. (2008). A systemic review of epidemiological studies investigating risk factors for work related road traffic crashes and injuries. *Journal of Injury Prevention*, *14*, 51-58.

Salmon, P.M., & Lenne, M.G. (2009). *System based human factors analysis of road traffic accidents: Barriers and solutions*. Australasian Road Safety Research Policing and Education Conference, Sydney NSW.

Salmon, P.M., Read, G.J.M., Stanton, N.A., & Lenne, M.G. (2013). The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings. *Journal of Accident Analysis and Prevention*, *50*, 1278-1288. DOI: https://doi.org/10.1016/j.aap.2012.09.029.

Toft, Y., Dell, G., Klockner, K.K., & Hutton, A. (2012). Models of causation. In HaSPA (Health and Safety Professionals Alliance). *The Core Body of Knowledge for Generalist OSH Professionals*. Tullamarine, Victoria. Safety Institute of Australia.

Timulak, L. (2009). Meta-analysis of Qualitative studies: A tool for reviewing qualitative research findings in psychotherapy. *Journal of Psychotherapy Research*, *19*(4-5), 591-600. DOI:10.1080/10503300802477989.

Transport Policy. (2021). *Modes: Heavy duty vehicles.* https://www.tranpsortpolicy.net/transport-modes/heavy-duty-vehicles/.

Transport Safety Investigations Act 2003 (ACT).

Victorian Parliament Law Reform Committee. (2006). *Inquiry into the review of the Coroners Act 1985*. Parliamentary Paper No. 229 of Session 2003-06. ISBN-0-9757984-1-3, Melbourne Victoria.

AUTHORS

Ivan Cikara is a PhD Candidate at Central Queensland University completing his PhD on heavy vehicle fatal crash investigations titled 'Systemic investigations are needed to improve safety in the heavy vehicle transport industry'. Ivan has over 30 years' experience working in both the Government and private sectors. This includes working in Policing where the main focus of his duties was on fatal crash investigations, before progressing to the Homicide Squad as a Senior Detective. Ivan's career continued into investigations management in the medical and health industry as well as safety and investigations management in the transport, maritime, rail, mining and oil and gas sectors, holding a number of senior executive roles.

Dr. Geoff Dell is a Professor at Ostrava University and Adjunct Professor at Central Queensland University. Dr Dell was also the former Head of Safety Science Courses. He is a career Safety Scientist with 40 years of senior safety management roles in aviation, rail and other industries. Dr Dell was National President of the Safety Institute of Australia for 9 years and the Independent Safety Adviser and Member of the Board of Directors of Cobham Aviation Services, the third largest airline in Australia, and was the independent Chairman of the Board Safety Sub-committee of Nauru Airlines for 2 years. In 2010, he joined CQUniversity to develop and implement the world first tertiary education courses in accident investigation including the unique Bachelor of Accident Forensics and the Master of Accident Investigation

Dr. Aldo Raineri is currently the Head of Courses – Safety Science, CQ University Brisbane. In December 2011 Dr Raineri retired as the Director of Work Health & Safety Policy & Legislation, after having spent over 20 years in various management and safety roles with the Queensland Government. During that time, Dr Raineri was involved in every major strategic and operational government safety initiative, including the national development of harmonised work health and safety laws and their implementation in Queensland. Dr Raineri has also been a sessional lecturer, tutor, course developer, educational administrator and project supervisor in the TAFE system and at a number of Universities in Australia for the past 30 years.

Shevaun Dell is an accident forensics educator who is passionate about improving the quality and transparency of the communication of research and scientific findings to the broader community. Trained in forensic science, psychology and criminology, she has taught at Central Queensland University and been involved in a variety of safety science research projects ranging from transport domain accident investigations to workplace bullying and stress. She is currently completing a forensic psychology-related PhD research study.

World Safety Journal

A peer-reviewed journal,
published by the World Safety Organization

Journal Homepage:
https://worldsafety.org/wso-world-safety-journal/

The economic cost of road traffic accidents in Lebanon

Elias M. Choueiri[1*], Elie Otayek[2], and Alain Saroufim[3]

[1] *WSO Board Member and Liaison Officer to the United Nations*
[2] *Adjunct Professor, Western Sydney University, Australia*
[3] *Teaching Assistant and Ph.D. Candidate, Department of Civil and Material Engineering, UIC, USA*

KEYWORDS

Road Traffic Accidents
Accident Cost
Willingness-to-pay
Human Capital
Lebanon

ABSTRACT

Although it is estimated that more than 1,000 people are killed in road traffic accidents in Lebanon each year, only about 500 people are documented to have died as a result. The continued economic cost of the rising number of traffic accidents is significant and accounts for between 3.2 and 4.8 percent of Lebanon's Gross Domestic Product (GDP). Unfortunately, no laws or regulations exist in Lebanon to separate and protect the most vulnerable road users, such as pedestrians and motorcyclists, who suffer disproportionately in traffic accidents and account for 30 to 40% of all fatalities on the road. Although Lebanon has introduced a number of tested best practices for driving safety, many of them are not consistently enforced. For instance, about 15% of front seat passengers are listed as wearing seat belts.

This paper's primary objective is to quantify the cost of road traffic accidents in Lebanon. For estimation, two methods are used: (1) the willingness to pay (WTP) approach, which values society's willingness to pay for avoiding death, injury, and damage outcomes from road crashes; and (2) the human capital (HC) approach, which evaluates the economic loss based on the expense relative to a person's injury, lost income, and property damage.

1. INTRODUCTION

It is estimated that around 1.3 million people lose their lives as a direct result of automobile accidents every year. Between 20 and 50 million additional people experience injuries that do not result in death, with many of these people developing a disability as a direct result of road accidents. Individuals, families, and nations suffer significant financial losses as a result of these accidents; the losses are the result of the cost of treatment, lost productivity for individuals who have been rendered unable to work as a result of injuries, and the time taken off by family members to care for those who have been hurt. According to the World Health Organization, countries lose about 3% of their gross domestic product due to traffic accidents (WHO).

According to recent public health statistics in the MENA region (Middle East and North Africa), the leading cause of death among young adults is car accidents. In terms of socioeconomic measures, such as accident fatality rates, healthy years of life lost due to accidents, and percentage of GDP lost, MENA

* ***Corresponding Author***: elias.choueiri@gmail.com

https://doi.org/10.5281/zenodo.6790784

countries are now among the world's worst performers (Dahdah and Bose, 2013). This is due to a mix of risk factors, including excessive speeding coupled with a lack of police enforcement and an inadequate punishment system; rapid motorization expansion, and road construction coupled with inadequate road design.

Since the civil war (1975–1990), Lebanon, a MENA country, has lacked an efficient transportation infrastructure, resulting in a high reliance on private car use, which has exacerbated road traffic congestion, especially in the Greater Beirut Area (GBA), where half of the population lives, making the daily commute to Beirut's city center an ordeal for many people. In addition, the situation has worsened in recent years as a result of the movement of 1.5 million Syrian refugees, who now make up around 25% of Lebanon's permanent population; this has led to a 15–25% increase in road traffic. Lebanon's high reliance on private cars, which is rapidly becoming a transportation nightmare, not only causes severe road traffic congestion, especially during peak hours, but also has significant environmental consequences in terms of noise and air pollution, as well as economic consequences for the country. According to studies conducted for the Ministry of Environment, the cost of urban road traffic congestion in the Greater Beirut Area (GBA) is 8-10% of Lebanon’s gross domestic product (Kadi, 2016). In terms of road accidents, the situation in Lebanon is exacerbated by the fact that 30-40% of fatalities involve vulnerable road users, such as pedestrians and motorcyclists.

Lebanon's road safety record is among the worst in the world. Unfortunately, Lebanon's cash-strapped government does not prioritize road safety. The lack of safety features in most automobiles is the leading cause of fatalities on the road. Despite the fact that accidents involving safety-equipped vehicles result in significantly fewer fatalities, Lebanon has no law mandating safety features such as backseat head rests (to prevent neck or back injuries), air bags, anti-lock braking systems (ABS), and electronic stability programs (ESP) to control skids, which are standard and, in some cases, required in the United States and parts of Europe. According to the World Health Organization (WHO), over 1,000 people (adjusted number of deaths) are killed and over 10,000 are injured annually on Lebanon's roadways (see Table 1). Noteworthy is that the mortality rate in Lebanon is higher than the comparable rates in countries of Europe and the USA (see Table 2).

The majority of automobiles in Lebanon are potentially hazardous due to worn-out tires, brakes, and shock absorbers, as well as the absence of safety equipment. Although Lebanon has an annual system for certifying the roadworthiness of automobiles, there are no regulations barring the entry of junk cars from Europe, where they are illegal to drive. These European automobiles with tens of thousands of kilometers on the odometer are altered and sold as "used" in countries with lax regulations, such as Lebanon.

Inexperienced and irresponsible motorists complete the lethal equation. Obtaining a driver's license in Lebanon requires more bureaucratic skills than driving aptitude, and it is not indicative of a driver's skill. Those who can afford to pay baksheesh (under-the-table bribes) are known to send factotums to get licenses in their place. Using a cell phone, eating, drinking, and exchanging money (for passengers in commercial vehicles) are common while driving. On a private motorcycle, the children are pushed between their father, who is perched on the gas tank, and their mother, who is normally positioned sidesaddle on the back rack with another child in her arms. Helmets and seatbelts are required for drivers and people sitting in the front seats of cars (but not for people sitting in the back seats), but these rules are rarely followed, just like speed limits (Choueiri et al., 2015).

Lebanese legislation set speed limits on urban roads nationally at 100 km/h and allowed local authorities to set lower limits. However, enforcement of speed limits is only effective at a rate of 4 to 10, which is low but much more effective than the enforcement of the drink-driving law. The legal

https://doi.org/10.5281/zenodo.6790784

limit for the latter is set at 0.05g/dl but barely has any efficacy when it comes to enforcement. Random breath testing and/or police checkpoints are occasionally set up, but there is no tracking of data related to road deaths caused by alcohol consumption. The seat-belt wearing rate remains low; according to the Lebanese Internal Security Forces, only 15% of the population buckles up. Enforcement effectiveness scores low too. On the other hand, Lebanon has not yet introduced a child restraint law. As for helmet wearing rates, no data is available. Despite a motorcycle helmet law, helmet standards are not mandated and weakly enforced (Choueiri et al., 2015).

This paper's primary objective is to quantify the cost of road traffic accidents in Lebanon. For estimating, two methods are used: (1) the willingness to pay (WTP) approach, which measures how much people are willing to pay to avoid death, injury, and damage from car accidents; and (2) the human capital (HC) approach, which figures out the economic loss based on the cost of treating the person's injury, lost income, and property damage.

Table 1. Road safety in the Middle East: number of deaths and road mortality rate

Ranking	Country	Reported number of deaths	Adjusted number of deaths	Mortality rate 2015
1	Jordan	768	1 913	25.1
2	Saudi Arabia	7 661	7 898	25
3	Oman	913	924	20.57
4	Yemen	3 239	5 248	19.55
5	Iraq	5 789	6 826	18.74
6	Lebanon	630	1 088	18.59
7	Kuwait	473	629	16.16
8	Qatar	204	330	14.76
9	Egypt	8 701	10 466	11.43
10	United Arab Emirates	651	1 021	11.14
11	Bahrain	83	107	7.77

***Source**: World Road Safety Report, World Health Organization (WHO), International Organization of Motor Vehicle Manufacturers (OICA)*

Table 2. Road safety in the rest of the World: number of deaths and road mortality rate

Ranking	Country	Reported number of deaths	Adjusted number of deaths	Mortality rate 2015
1	Brazil	41 059	46 935	22.58
2	Russia	27 025	27 025	18.75
3	Chile	2 108	2 179	12.14
4	Mexico	17 139	15 062	11.85
5	United States	32 719	35 092	10.91
6	Greece	865	1013	9.35
7	Croatia	368	395	9.35

https://doi.org/10.5281/zenodo.6790784

Table 2 (cont.). Road safety in the rest of the World: number of deaths and road mortality rate

Ranking	Country	Reported number of deaths	Adjusted number of deaths	Mortality rate 2015
8	Turkey	4 786	6 687	8.5
9	Czech Republic	654	708	6.7
10	Belgium	724	732	6.48
11	New Zealand	253	272	5.9
12	Slovenia	125	120	5.81
13	Canada	2 077	2 114	5.8
14	Portugal	637	593	5.73
15	Italy	3 385	3 428	5.63
16	Australia	1 192	1 252	5.2
17	France	3 268	3 461	5.18
18	Germany	3 339	3 540	4.34
19	Spain	1 680	1 689	3.6
20	Switzerland	269	269	3.24
21	Netherlands	570	531	3.13
22	Denmark	191	178	3.1
23	United Kingdom	1 770	1 806	2.77
24	Sweden	260	272	2.7

***Source**: World Road Safety Report, World Health Organization (WHO), International Organization of Motor Vehicle Manufacturers (OICA)*

2. QUANTIFYING THE COST OF TRAFFIC ACCIDENTS IN LEBANON

To be able to quantify the overall cost of road traffic accidents in Lebanon or to determine the unit costs, i.e. cost per casualty, from aggregate cost data, it was important to obtain detailed information on road traffic accidents. Unfortunately, previous studies revealed significant underreporting issues concerning road accidents. Underreporting is caused by both definitional inconsistencies and the failure to report some accidents (Choueiri et al., 2015).

2.1 Definition of Road Fatality

According to the Vienna Convention on Road Traffic (Vienna, 1968), a person killed in a road accident is defined as "any individual who was killed outright or died within 30 days as a result of the accident" (UN, Treaty Collection). The Lebanese definition is: "A fatality originating from a traffic accident that occurs either on the spot or while the injured individual is being treated in a hospital for the accident's damage, regardless of how long he or she is hospitalized before dying." As long as the injured person is still in the hospital, there is no precise number of days between injury and death.

https://doi.org/10.5281/zenodo.6790784

If hospital information is included in accident statistics, then the statistics include people who die within 30 days or more, if they die at the hospital. Hospitals, on the other hand, do not report all fatalities to the Traffic Emergency Committee (TEC) at the Internal Security Forces (ISF), despite several efforts to increase this reporting. TEC records nearly as many fatalities as private crash investigators (PCI), who do not have access to hospital records. If only fatalities on the spot, or victims who die within 24 hours are included, then international practice suggests an increase in the number of recorded fatalities; for instance, the World Bank applies a multiplication factor of 1.9 (The World Bank: Lebanon's Road Safety country Profile).

Noteworthy is that a road injury in Lebanon is defined as a physical harm caused by an accident, whether treated in a hospital or at the scene by rescue teams (Red Cross) in the presence of an inspecting officer. This concept is further broken down into serious and minor injuries. The Lebanese definition of "serious injury" is similar to that of many other countries (Belgium, Canada, Germany, Luxembourg, Spain, and so forth); it is an injury that places the afflicted person's life in jeopardy and necessitates hospitalization for more than 24 hours. It cannot be handled by rescuers or hospital emergency rooms, whose responsibility is confined to keeping the injured individual alive until professional medical personnel arrive. A minor injury is described as one that may be treated on the spot by rescuers or at a hospital's emergency room. It is also an injury that does not require more than 24 hours of hospitalization before the patient can leave the hospital or the medical facility.

2.2 Overview of Possible Sources of Road Accident Information in Lebanon

Road accidents in Lebanon are investigated by the traffic police, who then report the number of victims, fatalities, and injuries to TEC. The phases of the accident cycle are shown in the following figure (Republic of Lebanon, Ministry of Public Works & Transport, 2004).

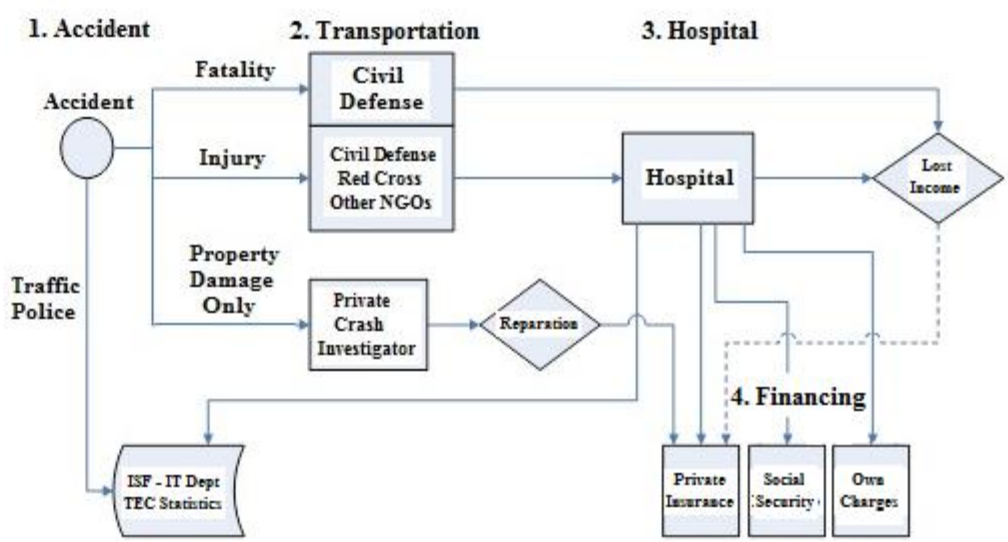


Figure 1. Phases of the 'accident cycle'

Typically, the Red Cross takes care of transporting people who have been injured in road accidents; noteworthy is that 80% of all injured people in Lebanon are catered for by the Red Cross. With respect to road fatalities, the civil defense usually take charge.

https://doi.org/10.5281/zenodo.6790784

With respect to property damage only accidents, private crash investigators take charge and fill out accident reports, which include specifics, such as the approximate cost of material losses, the culpability associated with the accident, the number of people involved, and so forth. A group called "Syndicate of Lebanese Traffic Experts" (SOTREX) is in charge of accident investigations.

Insurance companies take charge of claims, number of accidents, fatalities and injuries, as well as current and future costs.

2.3 Road Accidents and Underreporting

According to the Lebanese Internal Security Forces' (ISF), the road safety predicament in Lebanon is greatly underestimated due to serious underreporting problems. Underreporting is a problem that exists in every country's accident statistics; the problem of underreporting appears to become more severe if the severity of an accident is diminished. Data on accidents does not differentiate between less serious and more serious injuries; besides, the criteria that different organizations apply are quite varied. Because of this, the way injuries are defined has a big impact on the total number of accidents, and their consequences, reported by different organizations.

2.4 Evaluation of Crash Cost Values

The Human Capital (HC) and Willingness-to-Pay (WTP) methodologies are the two main approaches used in industrialized nations to calculate crash cost values. The HC method calculates the economic loss based on the expense of treating a person's injury, determining lost income and property damage. Costs for pain and suffering brought about by injury or fatality accidents are also regarded in some HC approaches. Even though this is taken into account, it is still believed that this method, which focuses on economic costs, underestimates the real cost of an accident.

The results of surveys asking individuals how much they would be willing to spend to reduce particular types of risk are the foundation of the WTP strategy. As a result, it assesses the value of preventing traffic accidents, or the price society is willing to pay towards safety improvement. Because it more accurately captures the complete social and economic consequences of fatalities and damages, this approach is seen as more conceptually sound, but it also has certain methodological problems (with respect to the development of survey instruments, and the cost of gathering relevant data).

3. MATERIAL AND METHODS

3.1 Sample Population

This cross-sectional study was conducted on a representative sample of drivers over 18 years of age. The following equation was used to figure out the minimum number of drivers to survey:

$$N = p * q * (z_{\alpha/2}/d)^2 \quad (1)$$

where:

- N: Minimum required sample size
- p: Proportion of drivers who respond positively to the survey;
- q: Proportion of drivers who respond negatively to the survey (q = 1-p);
- d: Permitted error; and
- $z_{\alpha/2}$: Critical "z" value derived from the standard normal distribution table, where the subscript α/2 denotes the tail area.

https://doi.org/10.5281/zenodo.6790784

To determine the minimum sample size, "p" and "q" were assumed to be 0.5; the permitted error was taken as 0.05 at a 95% confidence level. As such, the estimated sample size was calculated to be 377 drivers.

3.2 Survey instruments

The survey instrument was a questionnaire that was adapted and adopted for repeated survey of the general population. It consisted of seven categories of questions: (1) **Demographics**, (2) **Driving Practices**, (3) **Driving Experience**, (4) **Driver Opinion**, (5) **Driver Self Evaluation**, (6) **Situational Driver Behavior**, and (7) **Willingness to Pay**. The main purpose of the questionnaire was to gather information on gender, age group, marital status, income level, owned cars, travel to destination, accident involvement, exposure to accidents, severity-related to accidents, and willingness to pay for increased road safety.

3.3 Participants

Drivers who were willing to take part in the study were required to complete a questionnaire that was posted on several social media sites and linked to a Google form so that it could be seen by others. At the end of the survey, only 380 drivers were taken into account, given that drivers who did not answer a good number of questions were left out of further analyses.

4. RESULTS

4.1 driver characteristics

The percentage distribution of the surveyed drivers by gender is displayed in Table 3. The proportion of male and female drivers among the respondents was nearly identical. A chi-square test revealed, at a significance level of 5%, that there was no gender difference among the respondents ($\chi^2(1) = 1.053$, $p = .305$).

Table 3. Frequency and Percent Distribution of Participants according to Gender

Gender	Frequency	Percent	Chi-Square Test	Sig
Male	200	52.6%	1.053	.305
Female	180	47.4%		

More than eighty-six percent of the respondents traveled for business purposes, while the remaining respondents traveled for educational or other purposes (see Table 4). At the 5% level of significance, a chi-square test revealed a significant difference between business and educational/other purposes ($\chi^2(1) = 203.379$, $p < .001$).

Table 4. Frequency and Percent Distribution of Participants according to Travel Reason

Travel Reason	Frequency	Percent	Chi-Square Test	Sig
Business purposes	329	86.6%	203.379	< .001
Educational or other purposes	51	13.4%		

https://doi.org/10.5281/zenodo.6790784

The majority of the respondents were between 18 and 29 years (93.7 percent), followed by those between 30 and 44 years (12 percent) and 45 to 59 years (12 percent). Notably, none of the respondents were 60 years or older (see Table 5). A chi-square test revealed a significant difference between the age groups at the 5% level of significance ($\chi^2(2) = 622.821$, $p < .001$).

Table 5. Frequency and Percent Distribution of Participants according to Age Group

Age Group	Frequency	Percent	Chi-Square Test	Sig
18 - 29 years	356	93.7%	622.821	< .001
30 - 44 years	12	3.2%		
45 - 59 years	12	3.2%		

The distribution of the respondents according to educational level shows that 86.3 percent possess a university degree or higher, followed by respondents who have completed secondary school (12.6 percent), and 1.1 percent who have completed primary school (see Table 6). The latter is understandable given that education in Lebanon is compulsory until completing the intermediate school cycle, which is accessible to all Lebanese students. Given that the government has no proper control over children who live in urban slums or in remote rural areas, approximately 95 percent of school-age children usually attend schools. At the 5% level of significance, a chi-square test revealed a significant difference in educational level among the respondents ($\chi^2(2) = 487.663$, $p < .001$).

Table 6. Frequency and Percent Distribution of Participants according to Educational Level

Educational Level	Frequency	Percent	Chi-Square Test	Sig
Elementary	4	1.1%	487.663	< .001
Secondary	48	12.6%		
University Degree or higher	328	86.3%		

As participation in the interview is restricted to those who are at least 18 years old, it is reasonable to assume that the vast majority of those who answer the survey will be married given that young adults in Lebanon are encouraged to marry at a young age (see Table 7). As the table reveals, over sixty-eight percent of the respondents are married. At the 5% level of significance, a chi-square test revealed a significant difference in marital status among the respondents ($\chi^2(3) = 241.16$, $p < .001$).

Table 7. Frequency and Percent Distribution of Participants according to Marital Status

Marital Status	Frequency	Percent	Chi-Square Test	Sig
Single	93	24.5%	241.16	< .001
Married	260	68.4%		
Divorced	21	5.5%		
Widowed	6	1.6%		

The majority of the respondents, or 62.1%, have annual incomes of less than 1 million Lebanese pounds (approximately $633 US), followed by respondents with incomes of between 1 and 2 million Lebanese pounds (22.1%), and finally, 15.8% of respondents have annual incomes of more than 2 million Lebanese pounds (see Table 8). These results are consistent with the income levels of the

https://doi.org/10.5281/zenodo.6790784

general population of Lebanon. A chi-square test revealed a significant difference in the respondents' income levels ($\chi^2(2) = 143.832$, $p < .001$).

Table 8. Frequency and Percent Distribution of Participants according to Income Level

Income Level	Frequency	Percent	Chi-Square Test	Sig
Under 1 million L.L.	236	62.1%	143.832	< .001
Between 1 and 2 million L.L.	84	22.1%		
2 million L.L. and over	60	15.8%		

According to the distribution of respondents by number of cars owned, the majority of the respondents (86.4 percent) indicated that they have access to more than one car at their household (see Table 9). This is logical given the limited availability of an efficient public transportation system. A chi-square test revealed a significant difference in the number of owned cars among the respondents at the 5% level of significance ($\chi^2(3) = 278.695$, $p < .001$).

Table 9. Frequency and Percent Distribution of Participants according to Owned Vehicles

Owned cars	Frequency	Percent	Chi-Square Test	Sig
1 car	52	13.7%	278.695	< .001
2 cars	228	60.0%		
3 cars	88	23.2%		
4 cars or more	12	3.2%		

Every day, 27.9 percent of the respondents travel between 10 and 14 kilometers to reach their intended destination, 22.6 percent commute between 15 and 19 kilometers, and 21.6 percent travel between 5 and 9 kilometers (see Table 10). A chi-square test revealed a significant difference in the respondents' daily travel to destination ($\chi^2(4) = 32.0$, $p < .001$).

Table 10. Frequency and Percent Distribution of Participants according to Travel to Destination

Distance to destination	Frequency	Percent	Chi-Square Test	Sig
Less than 5 km	40	10.5%	32.0	< .001
5 - 9 km	82	21.6%		
10 – 14 km	106	27.9%		
15 - 19 km	86	22.6%		
20 km and over	66	17.4%		

The vast majority (75.8 percent) of the respondents reported that at least one member of the family had been involved in an automobile accident (see Table 11). A chi-square test revealed a significant difference between the respondents according to accident involvement at the 5% level of significance ($\chi^2(1) = 101.095$, $p < .001$).

Table 11. Frequency and Percent Distribution of Participants according to Accident Involvement

Accident Involvement	Frequency	Percent	Chi-Square Test	Sig
Yes	288	75.8%	101.095	< .001
No	92	24.2%		

https://doi.org/10.5281/zenodo.6790784

In terms of injury severity, the majority of the respondents (53 percent) stated that either they or someone they know did not sustain injuries in road accidents, while 27.7 percent of the respondents stated that either they or someone they know sustained light injuries, and 9.6 percent of the respondents indicated that either they or someone they know sustained equally medium or serious injuries (see Table 12). A chi-square test revealed that there was a significant difference in severity type among the respondents ($\chi^2(3) = 190.147$, $p < .001$).

Table 12. Frequency and Percent Distribution of Participants according to Severity Type

Severity Type	Frequency	Percent	Chi-Square Test	Sig
Serious injuries	37	9.6%	190.147	< .001
Medium injuries	37	9.6%		
Light injuries	105	27.7%		
No injuries	201	53.0%		

More than 40% of those surveyed stated that they are likely to be involved in a car accident but are not certain. This was followed by over 30 percent who noted that it is likely to get involved but with a medium probability; twenty-three percent of the respondents indicated that it is unlikely that they will be involved in a car accident. Only 4.2% of the respondents noted that it is "probable" or "extremely likely" that they will be involved in a car accident during their lifetime (see Table 13). A chi-square test revealed a significant difference between the respondents according to the degree of exposure to road accidents at the 5% level of significance ($\chi^2(1) = 111.958$, $p < .001$).

Table 13. Frequency and Percent Distribution of Participants according to Accident Exposure

Degree of exposure to road accidents	Frequency	%	Chi-Square Test	Sig
Unlikely to be involved	88	23.2%	111.958	< .001
Likely but with a low probability	156	41.1%		
Likely but with a medium probability	120	31.6%		
Likely but with a high probability	16	4.2%		

4.2 Accident Cost Calculations

During the last two decades, one of the most discussed aspects of monetizing the level of road safety was the development of the so-called ‘Value of Statistical Life (VSL)’. Generally, pain, sorrow, and lost quality of life as a consequence of road accidents are regarded in this value. The methods of monetizing can be distinguished by means of approaches like the Human Capital (HC) approach and the Willingness-to-Pay (WTP) approach (Dionne and Lanoie, 2004).

The HC approach deals with the monetary contribution to society, whereas the WTP approach is based on the personal preferences of individuals. People show their willingness either to pay a specific amount of money for the reduction of an accident risk or to accept money for accepting the risk. Depending on the WTP method used, the value is either directly asked for or figured out from choice experiments.

Because the HC method does not provide enough weight to non-market goods, like avoiding pain or sadness, the WTP method is regarded as a good way to figure out the VSL.

4.2.1 *Willingness to Pay for Road Safety Improvement*

In Lebanon, the real risk of death in traffic accidents is 78 deaths per million people per year (as based on the unadjusted ISF figures); hence, a 50% reduction in risk results in 39 deaths per 1,000,000 people, while a 20% reduction results in 16 deaths per 1,000,000 people.

To ascertain the value of statistical life, the respondents were asked how much financial compensation they would be willing to contribute towards safety risk reductions of 50% and 20%, respectively. The following table summarizes the findings for each risk reduction strategy.

Table 14. Dollars per year for Options A and B

$/year	Option A (50% risk reduction)	Option B (20% risk reduction)
2.50	24	40
5.00	20	24
10.00	52	44
25.00	28	52
50.00	76	76
75.00	8	20
100.00	64	20
125.00	4	50
150.00	100	48
Total	**376**	**374**

The table below provides descriptive statistics of risk reductions.

Table 15. Relevant Descriptive Statistics for Options A and B

Option	N	Mean ($ per year)	Std. Deviation ($ per year)	Median ($ per year)
A (50% risk reduction)	376	73.62	55.93	50
B (20% risk reduction)	374	60.40	52.36	50

Option A (50 percent risk reduction) reduces the annual accident risk by $73.62, whereas Option B (20 percent risk reduction) reduces the annual accident risk by $60.40. The median value for both risk reductions is $50.

Given that the actual risk of death in car accidents in Lebanon is about 78 deaths per million people per year (as based on the unadjusted ISF figures), Option A (50 percent risk reduction) implies that the statistical value of life is:

$$\frac{\$73.61}{year} \times \frac{1,000,000}{39} = \$1,887,436$$

In the case of Option B (20% risk reduction), the value of statistical life is:

$$\frac{\$60.40}{year} \times \frac{1,000,000}{16} = \$3,775,000$$

https://doi.org/10.5281/zenodo.6790784

While it is obvious that the respondents were prepared to pay a premium for a reduced safety risk, they were unable to distinguish between low and high risks. As a result, the values for options A and B varied significantly with respect to VOSL.

Table 16. Overall cost of the life loss in dollars per year

Year	Population	Number of road fatalities as per ISF	Average of VOSLs (in dollars) for 20% and 50% risk reduction	Overall cost of the life loss in dollars per year
2007	3,986,852	487	$2,831,218	$1,378,803,166
2008	4,111,000	333	$2,831,218	$942,795,594
2012	4,337,141	378	$2,831,218	$1,070,200,404
2014	5,603,000	537	$2,831,218	$1,520,364,066
2015	5,851,479	575	$2,831,218	$1,627,950,350
2016	6,006,668	472	$2,831,218	$1,336,334,896
Average / year				**$1,312,741,413**

However, the amount shown above is the bare minimum because it only considers the number of road fatalities, without reference to serious, medium, minor injuries and property damage only accidents. Studies have shown that a serious injury accounts for 10% of a road fatality; a minor injury accounts for 1% of a road fatality; and a property damage only accounts for 0.1 percent of a road fatality. These percentages are applied in the following table to estimate the overall cost of road accidents in Lebanon.

Table 17. Adopted percentages to determine the overall cost of accidents

Injury Severity	Number (2016)	VOSL in $	Total Cost
Fatalities	472	$2,831,218	$1,336,334,896
Serious injuries (10% of a fatality cost)	594	$283,122	$168,174,468
Minor injuries (1% of a fatality cost)	2536	$28,312	$71,799,232
Property Damage Only (0.1% of a fatality cost)	21732	$2,831	$61,523,292
Total Cost			**$1,637,831,888**

Because not all traffic accidents are reported to the police, coupled with problems, such as cover-ups and missing accident reports, the total cost shown above represents the least amount of money associated with road accidents.

It should be noted, without delving into details, that unmarried respondents (who tended to be relatively young) had higher WTP values than married respondents; the reason being is that married respondents typically have a greater responsibility at home in terms of providing support to families. Furthermore, the WTP values decreased with increased age and larger family size; in this respect, younger respondents were found to adopt higher WTP values, as compared to older respondents. It was interesting to note that education, economic standing and distance to destination positively influenced WTP, implying that advanced years of studies and better economic standing were associated with higher WTP values.

https://doi.org/10.5281/zenodo.6790784

4.2.2 Human Capital Cost

The table below summarizes the process of the HC approach adopted in this study to estimate the accident costs (Mofadal and Kanitpong, 2016; Silcock, 2003).

Table 18. Human Capital approach

Cost Component	Estimation Formula
Loss of Productivity	1) Lost productivity in terms of income loss due to fatalities = [No. fatalities × average age in years]×[foregoing income per year using $\sum_{i=1}^{N} W(1+g)^i/(1+r)^i$. 2) Lost productivity in terms of income loss due to serious injury = [No. of serious injuries]×[No. of days in hospital] ×[average wage per day]. 3) Lost productivity in terms of income loss from Middle and slight injuries (during treatment or recovery period) = [No. of Middle injuries]× [No. of days in hospital]×[average wage per day] + [No. of slight injuries]×[No. of days in hospital] ×[average wage per day]. 4) Lost output in terms of income loss due to time lost normally spent by casualties with their families and community in social activities. = [No. fatalities]×[No. of hours per lost years]×[average wage per hour] + [No. of disabilities] ×[No. of hours per lost month] ×[average wage per hour]+[No. of injuries] ×[No. of hours per lost days] × [average wage per hour].
Loss Due to Quality of Life Costs	Total quality of life costs = [No. of fatalities] ×[amount compensated by insurance companies] + [No. of injuries] × [amount compensated by insurance companies]
Medical Costs	1) Total medical costs (disabilities)= [No. of disabilities cases with facture injuries]×[average hospitalization days] ×[average hospitalization expenses per/person/day]. 2) Total medical costs (serious injury) = [No. of serious injury cases]×[average hospitalization days]×[average hospitalization expenses per/person/day]. 3) Total medical costs (slight injuries) = [No. of slight injury cases]×[average hospitalization days]×[average hospitalization expenses per/person/day]
Vehicle Damage and Detention Costs	1) Total vehicle damage costs = [No. of total vehicles damaged]×[average vehicle damage costs] 2) Total vehicle detention costs = [No. of total repaired vehicles (by vehicle type)]×[average vehicle repair period (in days)]×[average vehicle rental cost/day]

https://doi.org/10.5281/zenodo.6790784

The following figures were taken into consideration in determining the final cost:

- **Accident Severity**
  - Serious Injury: $1494.17
  - Medium Injury: $1162.35
  - Light Injury: $720.42
- **Average Annual GDP per Capita**
  - $6983.7
- **Average Annual Growth Rate**
  - 4.26%
- **Discount rate**
  - 3.5%
- **Average Number of Lost Output Years**
  - 31 years
- **Administrative Costs**
  - 10% to the total cost derived from human and vehicle costs.

As a result, the total cost associated with road accidents and the overall cost derived from the HC approach are shown in the table below.

Cost Category	Estimated Cost in $US	Percentage	Percentage of Total Cost
Human Costs			
Loss of Productivity	$1,050,280,531	94.55%	81%
Loss due to Quality of Life Costs	$30,944,000	2.79%	2%
Medical Costs	$29,596,760	2.66%	2%
Subtotal	**$1,110,821,291**	**100%**	**85%**
Vehicle Costs			
Vehicle Damage Costs	$65,196,000	92%	5.0%
Vehicle Detention Costs	$5,324,340	8%	0.4%
Subtotal	**$70,520,340**	**100%**	**5.4%**
General Costs			
Policing Costs	10% of the total cost	100%	9%
Court Costs			
Insurance Costs			
Subtotal	**$118,134,163**		
Total Accident Costs	**$1,299,475,794**		

As can be deduced from the above table, the HC approach yields an accident cost figure of $1,299,475,794.

5. DISCUSSION AND CONCLUSIONS

This study, one of the first on the economic cost of road traffic accidents in Lebanon, reveals that the minimum costs associated with road accidents, as determined by the WTP and HC approaches, are quite high; for example, in 2016, the costs determined by the WTP approach were $1,637,831,888, while the costs determined by the HC approach were $1,299,475,794. These figures are based on

https://doi.org/10.5281/zenodo.6790784

unadjusted ISF road fatality and injury statistics. If the World Bank's correction factor of 1.9 is applied (The World Bank: Lebanon's Road Safety Country Profile), then the amounts calculated in this study would nearly double and become comparable to those determined by the World Bank, or $2,767,000,000 for 2016.

According to the WTP approach, the accident cost rises to $3,111,880,587.2 (or 6.077 percent of the country's GDP); however, the cost rises to $2,469,004,008.6 (or 4.821 percent of the country's GDP) according to the HC approach. The average of the two approaches is $2,790,442,297.9, or 5.449 percent of the Lebanon's GDP, which are very close to the World Bank's figures for 2016 ($2,767 million and 5.4 percent of the Lebanon's GDP) (The World Bank: The World Bank in Lebanon; The World Bank: Lebanon's Road Safety Country Profile). Despite the availability of statistics on road traffic injuries in Lebanon, underreporting of road traffic deaths and injuries remains a significant concern that prevents an accurate assessment of Lebanon's burden. However, based on the limited data available, road traffic injuries appear to pose a significant threat to national health.

By all means, the accident costs determined in this study are significant in a country like Lebanon, which has been plagued by multiple problems for nearly three years, including an economic and financial crisis, COVID-19, and the August 4, 2020 explosion at the Port of Beirut. The most negative (and longest-lasting) impact has been the economic crisis. According to the World Bank's Spring 2021 Lebanon Economic Monitor (The World Bank: Lebanon Economic Monitor), Lebanon's economic and financial crisis is expected to be one of the top ten, if not the top three, most catastrophic crises to occur since the mid-nineteenth century.

Without a doubt, the economic and financial crisis has had a negative impact on roads, highways, road safety, and motorists. Due to prohibitively expensive spare parts, an increasing number of motorists are finding it difficult to maintain their vehicles, putting themselves and other road users at risk; they no longer have the means to change tires, replace headlights, windshield wipers, brakes, and shock absorbers, etc. Even though Lebanese are well aware of the risks, car maintenance has become less of a priority for those burdened by increasingly exorbitant bills; in order to avoid an unexpected bill, some drivers attempt to extend the life of defective parts for as long as necessary.

In conclusion, a corrupt political Lebanese class, obedient policymakers, and cronies have created unprecedented misery, resulting in an economic, banking, and financial meltdown. Their pervasive corruption, criminal negligence, and incompetence have brought the Horses of the Apocalypse disaster to Lebanon and its people, and road infrastructure and safety. The so-called ‘Lebanese politicians and elites’ profit from the corrupt system — and foreign donors keep propping them up to hang onto their own influence.

REFERENCES

Choueiri E.M., Choueiri G.B., and Choueiri B.M. (2015). Road safety in Lebanon: magnitude, cost and potential countermeasures. Advances in Transportation Studies, Section B 35, pp. 73-88.

Dahdah S. and Bose D. (2013). Road traffic injuries: a public health crisis in the Middle East and North Africa. The World Bank, Transport Notes, TRN-45.

Dionne G. and Lanoie P. (2004). Public Choice about the Value of a Statistical Life for Cost-Benefit Analyses: The Case of Road Safety. Journal of Transport Economics and Policy, University of Bath, vol. 38(2), pages 247-274, May.

Kadi S. (2016). Traffic Congestion Adds to Lebanon’s Many Woes. The Arab Weekly.

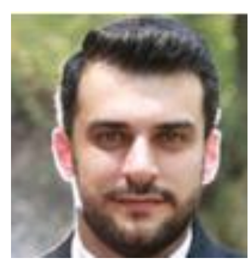
Mofadal A. and Kanitpong K. (2016). Analysis of Road Traffic Accident Costs in Sudan Using the Human Capital Method. Open Journal of Civil Engineering, vol. 6(2), March.

Republic of Lebanon, Ministry of Public Works & Transport (2004). The Cost of Road Traffic Accidents. Technical Report, SIDA Reference No. 2000-04865, May.
Silcock R. (2003). Guidelines for Estimating the Cost of Road Crashes in Developing Countries. Technical Report. Retrieved from: http://www.transportlinks.org/transport_links/filearea/documentstore/105_R%207780.PDF).
United Nations: Treaty Collection. Convention on Road Traffic. Retrieved from: https://treaties.un.org/Pages/ViewDetailsIII.aspx?chapter=11&mtdsg_no=XI-B-19&src=TREATY
The World Bank: Lebanon Economic Monitor, Spring 2021: Lebanon Sinking (to the Top 3). Retrieved from: https://www.worldbank.org/en/country/lebanon/publication/lebanon-economic-monitor-spring-2021-lebanon-sinking-to-the-top-3
The World Bank: Lebanon's Road Safety Country Profile. Retrieved from: https://www.roadsafetyfacility.org/country/lebanon
The World Bank: The World Bank in Lebanon. Retrieved from: https://www.worldbank.org/en/country/lebanon/overview
World Health Organization. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

AUTHORS

Prof. Dr. Elias M. CHOUEIRI has been very active in academic and research settings for over 35 years. He is the author/co-author of over 20 books and booklets, and hundreds of refereed publications, technical reports, conference presentations and newspaper articles. He has won more than 20 awards for his scholarship, and has held faculty and managerial positions at several public and private institutions in Lebanon and the USA. He is a member of the WSO Board of Directors, and serves as WSO Liaison Officer to the United Nations. Besides, he assumes the roles of Director of the WSO National Office for Lebanon, Chairperson of the WSO Highway Transportation Committee, and Chairperson of the WSO Transportation of Dangerous Goods Committee.

Dr. Elie OTAYEK, holds a Ph.D. in Building Engineering (Construction Management) from Concordia University, Montreal, Canada, with concentration in Structural engineering. He chaired the Civil Engineering Department at USEK University, Kaslik, Lebanon, between 2014 and 2019. He has over 25 years of experience in designing and managing construction projects in Lebanon, Canada, Australia and the Gulf Region. Since 2008, he has been a registered professional Engineer with Ordre des Ingenieurs du Quebec (OIQ) syndicate (Quebec, Canada). Besides, he is a Chartered Professional Engineer in Structural and Civil Works at Engineers Australia (EA), and is affiliated with the Order of Engineers and Architects (OEA) in Lebanon.



Alain SAROUFIM, Teaching Assistant and Ph.D. candidate at University of Illinois at Chicago, Department of Civil and Material Engineering. He holds a Bachelor of Engineering degree in Civil Engineering from the Holy Spirit University of Kaslik (USEK), Kaslik, Lebanon.

World Safety Journal

A peer-reviewed journal,
published by the World Safety Organization

Journal Homepage:
https://worldsafety.org/wso-world-safety-journal/

A platform management system that links commuters with shared or service taxis

Rony Darazi[1], Elias M. Choueiri[1*], Mira Bou Saleh[1], Elias Doumith[1], Anthony Tannoury[1], Abdulrahim Sekaki[2], Amir Hajjam Al Hassani[3]

1 Ticket Lab., Antonine University, Hadat-Baabda, Lebanon

2 Laboratoire de Recherche et Innovation Informatique (LR2I), Université Hassan II de Casablanca, Marocco

3 Nanomedicine-Imagery-Therapeutics Lab, Université de Technologie Belfort-Montbéliard, Besançon, France

KEYWORDS

Collective taxis
Public transportation
Information systems
Lebanon

ABSTRACT

This paper outlines a management system developed specifically for linking commuters in Beirut, Lebanon, with shared taxis (also known as "service"). In this paper, shared taxis are the ones that have been registered with the Syndicate of Lebanese Taxi Drivers. The objective of the system, which was distinguished by the absence of fixed transportation schedules and pre-defined stops, was to create a comprehensive platform called "Platform to Promote and Optimize Collective Taxi Access (PCT)" that provided commuters with a variety of route options between selected departure and destination points. The route options were selected and categorized based on the preferences of commuters. In Beirut, the findings of the initial prototype were deemed efficient and adequate in terms of unimodal mobility and providing commuters with a customized travel experience.

1. INTRODUCTION

A 15-year civil war transformed Beirut, once renowned as the "Pearl of the Middle East," into a true no-man's land (1975-1990). Parts of the city were demolished, roads were damaged, and train services were halted as a result. Since then, Lebanon has lacked a sustainable and efficient infrastructure and transportation system, which has exacerbated road congestion. Commutes in Lebanon have become a daily misery due to the country's severe traffic congestion. Lack of real efforts to modernize public transportation has also negatively impacted the economy of Lebanon. Access to low-cost collective transportation, such as shared taxis (or "service"), has become essential in this regard (Choueiri et al., 2015). However, the subject of encouraging and enhancing the relationship between commuters and communal transportation in Lebanon remained unsolved. Based on this foundation, the Antonine University in Lebanon initiated a project titled "Platform to Promote and Optimize Access to Collective Taxis," which featured both front-end and back-end systems, in an effort to increase commuters' awareness of collective transportation. The back-end of the platform was developed to optimize and encourage the use of collective transportation. It promoted shared taxis as the primary mode of transportation. This mode of transportation was characterized by the absence of predetermined transit times and stop locations. The project's major objective was to expand the use of shared taxis, notably in Beirut, by making them more accessible to anyone in need of transportation.

* ***Corresponding Author***: elias.choueiri@gmail.com

https://doi.org/10.5281/zenodo.6790841

2. RELATED WORK

Several transportation corporations and operators are developing innovative information technologies to make commuters' lives easier. These systems provide commuters with pre-trip information and real-time navigational guidance for transportation networks. Despite the fact that several routing applications are now in use, these systems do not always satisfy the expectations of commuters and are limited by a variety of constraints.

From this vantage point, the authors examined the merits and drawbacks of applications connected to both unimodal and multimodal modes of transportation. Numerous programs, including CIMO (Hassine and Canalda, 2015), TIMIPlan (Garcia et al., 2012), Busfinder (Tsolkas et al., 2012), and MaaS (MCMM, 2018); (Cole, 2018), have tackled unimodal and multimodal transportation difficulties.

TIMIPlan is an application that addressed both the Unimodal Transportation Problem (UTP) and the Multimodal Transportation Problem (MTP) for a large Spanish company. It expedited the transfer of resources and decreased the amount of time required. It addressed the MTP by combining Linear Programming (LP) with autonomous planning approaches, taking into account the limits imposed by both shared taxis (in terms of working hours) and consumers. To combat UTP, a MOACS (Multi-objective Ant Colony System) strategy was devised and applied, with several adjustments, such as allowing commuters to choose between reducing the number of automobiles and the total cost (Dib et al., 2016); Fiorenzo-Catalano, 2007); and Flórez et al., 2011).

CIMO (Calculateur d'Itinéraires Multimodaux Ordonnés) is a travel planner for the Belfort-Montbéliard region of France. The CTPM, SMTC, SMAU, SNCF, and Illicom networks comprise its transportation network. This repeated combination, employing a dynamic programming technique termed as "Cut, Price, and Share", did solve the MTP (Hassine and Canalda, 2015).

BusFinder is a mobile application designed to make Athens' (Greece) public transit more convenient. Based on a dynamic algorithm, the system provides a map depicting the various bus stops in the neighborhood of the commuter, as well as alternative routes of buses in the network, arrival times (taking into account traffic congestion), and navigation directions. Utilizing the DRO (Dynamic Route Optimization) method, this application processes real-time data from a Fleet Management System (FMS) and an Open Trip Planner (OTP). Overall, the application takes into account two steps: filtering data by deleting any extraneous information based on search queries and ranking results according to commuter preferences (Tsolkas et al., 2012).

MaaS is commonly viewed as a commuter-centric model of transportation that offers an on-demand, real-time platform that incorporates any combination of transport modalities, such as car, bike sharing, and taxis, and covers everything for the commuter, from journey planning to payments. It attempts to break down the barriers between the government transport agency, service providers, and transport operators, and to bring them closer to the customers. Using a single, unified trip planning and payment application, MaaS directs users to the most relevant mobility alternatives in real time (MCMM, 2018). MaaS offers itself as a subscription-based service that permits commuters to select several forms of transportation for a subscription fee or pay-as-you-go (Cole, 2018). MaaS can provide commuters with flexibility in selecting travel modes, timings, and costs in a city with multiple forms of transportation.

Hedi et al. (2009) and Ayed et al. (2011) offered a hybrid multimodal transportation solution. They used the ACO (Ant Colony Optimization) method to reduce the main memory consumption, resulting in an abstract graph that was a streamlined version of the original graph. The Dijkstra algorithm was then applied within an acceptable amount of time to determine the shortest route.

https://doi.org/10.5281/zenodo.6790841

Mahi et al. (2012) developed a routing algorithm to suggest a novel formulation for a multimodal network. On the Paris (and suburbs) transportation networks, this formulation was tested. Railways, buses, trams, metros, walking, automobile roadways, and bicycle paths were among the means of transportation studied. As optimization criteria, the authors utilized the total duration of the trip, the number of exchanges, and the total amount of time spent walking. Each network was modeled separately as a graph, as the initial step in their modeling procedure.

In addition, Mahi et al. (2012) distinguished between forms of private transportation that provided continuous service and modes of public transportation according to a predetermined timetable. In this way, every submodel was incorporated into a single global model. For example, the pedestrian network was used to shift from one mode to another; to link to the road network, parking lot nodes were utilized. Following network modeling, a modified version of Dijkstra's algorithm was employed to address the problem of shortest paths with several criteria.

Santos et al. (2007) provided three approaches for discovering the k-shortest paths: a route elimination algorithm, a deviation path algorithm based on the work of Eppstein (1998), and a deviation path algorithm with extra processing enhancement. In this regard, Martins and Pascoal (2003) examined a novel version of Yen's algorithm for rating loopless pathways.

3. THE PROPOSED PCT SYSTEM ARCHITECTURE

This paper describes a platform that can improve access to shared taxis in Lebanon that are registered with the Syndicate of Lebanese Taxi Drivers. In contrast to community transportation platforms and services offered in industrialized nations, shared taxis in Lebanon lack predetermined stop stations and regulated transit periods. In addition, they differ from shared transportation services, such as Uber and Careem, in that they do not offer reservation-in-advance choices; therefore, the commuter must hunt for or wait for the next available shared taxi that passes through his/her location. The approaches, including our recommended platform, are summarized in Table 1.

Table 1. The Comparative table between our approach and various solutions available

	Schedules	Way of moving	Meeting point	Booking Possibility
Collective transport in developed countries	Non-flexible but repetitive	The commuter	Predefined by stops	No
Uber and Careem	Flexible but non-repetitive	The shared taxi	Provided by the commuter	Yes
The project presented in this paper	Non-flexible and non-repetitive	The commuter	Set by the algorithm	No

https://doi.org/10.5281/zenodo.6790841

The five steps of our platform include data collection, graph construction, pre-processing, routing, and rating. Figure 1 depicts the steps of our platform; a detailed explanation of each level follows.

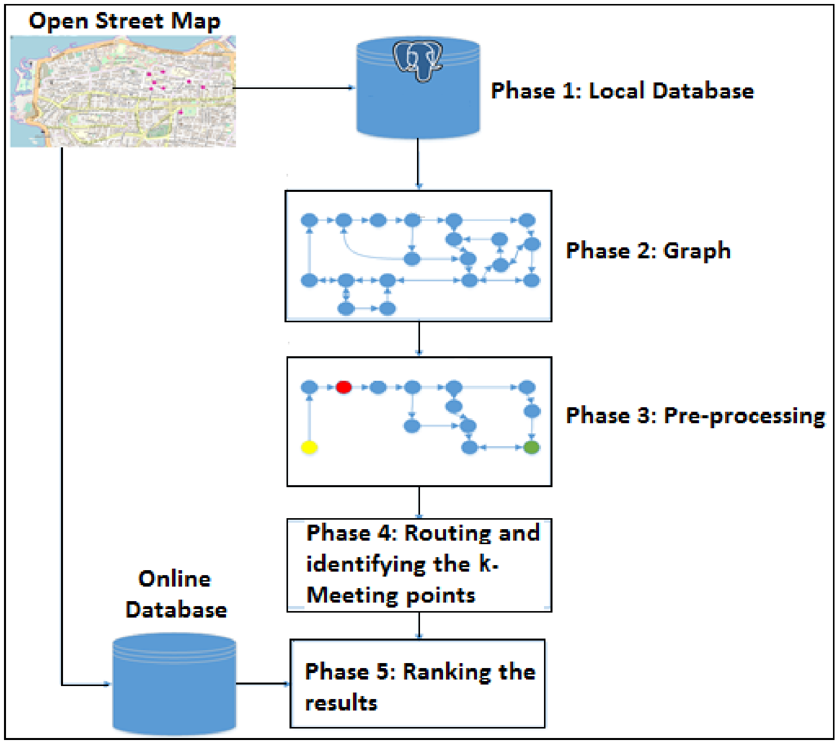


Figure 1. The proposed PCT System architecture

3.1 Data Collection

Regarding the local database, there were eleven tables. These eleven tables were divided into three categories: five tables pertaining to data from Lebanon's geographical map; five tables pertaining to data from platform commuters; and one table pertaining to the algorithm's output. The database is depicted in Figure 2.

We used "Open Street Map" for this purpose, as its data is considered an open source for acquiring geographic information. For this, we downloaded:

- the relational database management system-PostgreSQL;
- the Postgis software, which supports the addition of geographic objects to the PostgreSQL database;
- a file representing the geographical map of Lebanon of type ".OSM";
- the "OSM2Pgrouting" software, which converted the data from this file into tables based on the configuration chosen.

OSM_Nodes, OSM_WAY_TYPES, OSM_WAY_CLASSES, WAYS, and WAYS_VERTICES_PGR were the five tables relating to the geographical map of Lebanon. "weight_ s" and "reverse_weight_s" were added to the Ways table to reflect the time required for a pedestrian to cross the road from the starting location to the destination point.

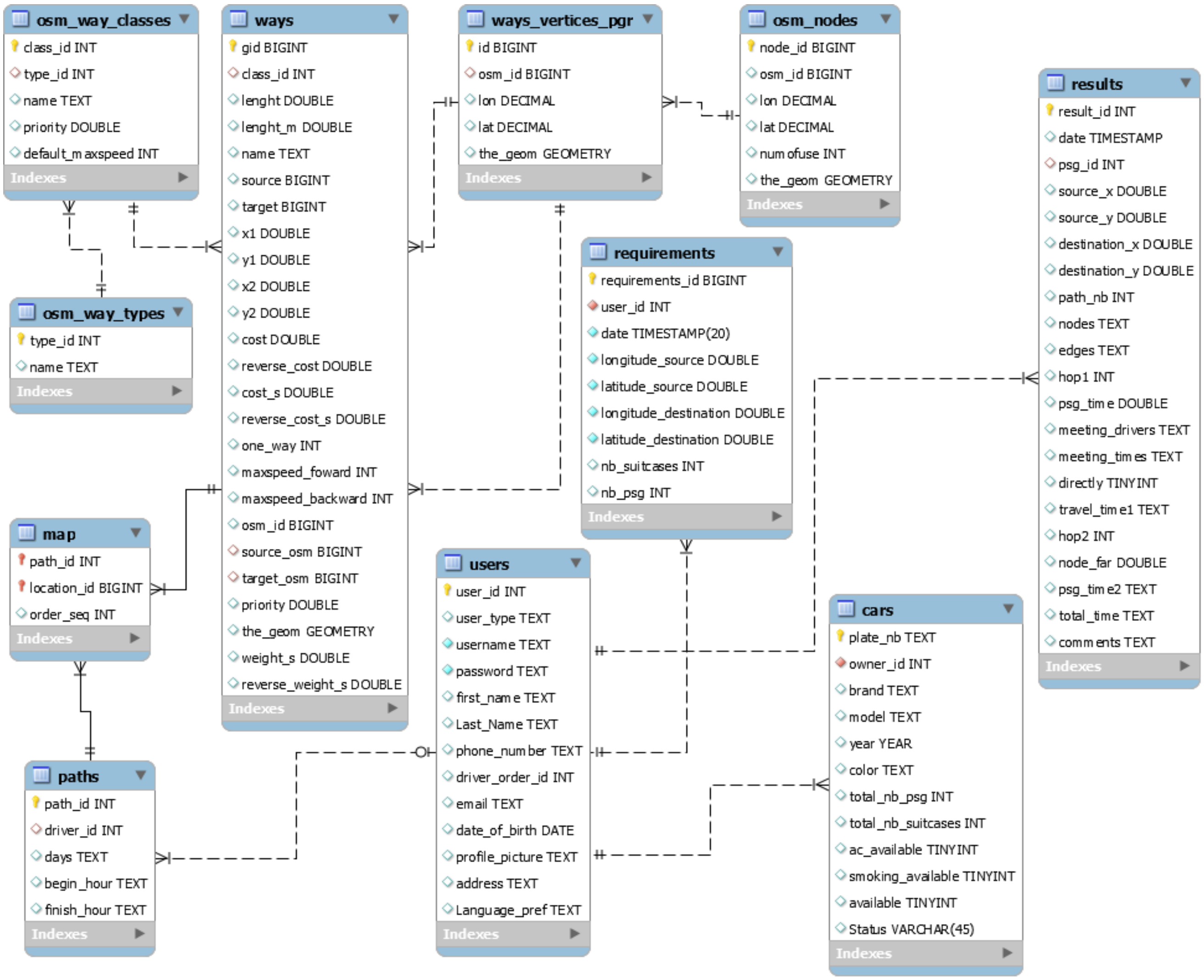


Figure 2. The database diagram

The five tables pertaining to commuters were likewise divided into two categories: two tables pertaining to the commuter, whether a driver or a commuter (commuters, requirements), and three tables pertaining to the driver alone (CARS, PATHS and MAP). These five tables were filled in by the platform's Front-End. In other words, the front-end portion of the platform was utilized to determine the commuter's attributes (personal information, location, requirements, vehicles, and paths).

Finally, a representative table of the routing algorithm's results (Results) was created. This table was loaded by the server-side component. It included the date of the routing request, the commuter's identification number, the commuter's initial location, and the commuter's ultimate destination. It also contained all of the nodes and arcs used to reach M-meeting-points and n-shared taxi-destinations while satisfying the commuter's request and the algorithm's constraints. In addition, it included the time required for commuters and shared taxis to reach the meeting locations, as well as the total duration.

3.2 Graph Creation

Following the acquisition of data, particularly those associated with the geographical map, the creation of the graph was initiated. The items of the Ways table created the arcs, whilst the elements of the Ways_Vertices_PGR table formed the nodes, with each Ways item connecting two Ways_Vertices_PGR elements.

https://doi.org/10.5281/zenodo.6790841

3.3 Pre-processing

This step preceded the phase of the algorithm. Therefore, it must provide the essential environment for algorithm execution. It pertains to:

- Determining the commuter's current location and desired final destination from the "requirements" table.
- Examining the commuter's position on the graph and determining if a virtual node and virtual arcs should be created for him or whether a node and an arc adequately define his position.
- Locating the target node, validating his position, and choosing whether a virtual node and virtual arcs should be created for him.
- Locating all available shared taxis in the vicinity of the commuter, including their positions and trajectories.
- Creating subgraphs for each shared taxi and commuter to reduce the number of nodes and arcs in the initial graph in order to facilitate the operation of the routing algorithm.

Figure 3 displays the procedure used. Noteworthy is that, in the case of shared taxis, the corresponding information, such as location, was regarded if the taxi was within a 1 km square, with the commuter at its center.

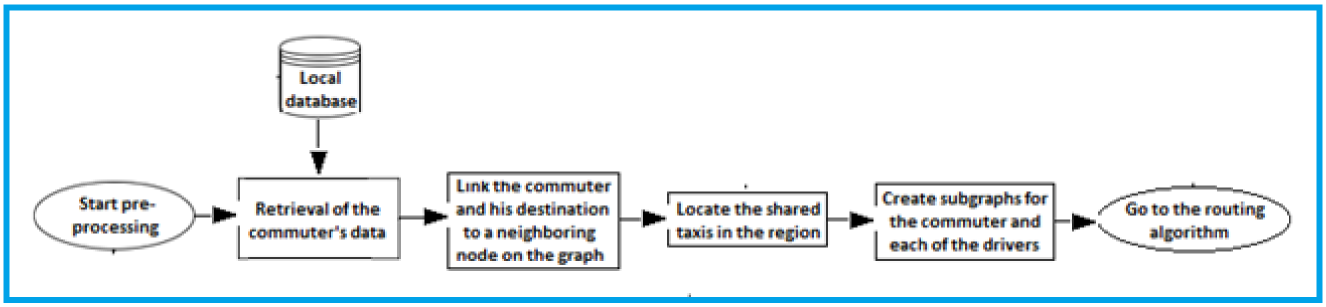


Figure 3. Pre-processing steps

In an effort to reduce the number of nodes and arcs in the initial graph, subgraphs were constructed following data extraction. Our proposed technique utilized the Yen algorithm to discover the 100 shortest paths between the commuter's current position and his final destination in order to construct the subgraphs relating to him. The shared taxis were then represented by a subgraph consisting of a succession of arcs representing their current locations and final destination.

3.4 Routing

Our suggested algorithm used computation, analysis, and decision-making techniques to present the location points where the commuter and shared taxis intersected, as well as the respective travel times. Noteworthy is that each location point must adhere to the constraint that the commuter's arrival time at the location point must be smaller than that of the shared taxi.

Our proposed approach pooled numerous shared taxis within the same intersecting nodes, hence eliminating redundancy. Each location point was also assigned a priority. Priority varied based on whether the shared cab traveled directly through the commuter's neighborhood, passed close to the commuter's destination, or neither of these.

https://doi.org/10.5281/zenodo.6790841

Figure 4 displays the methods performed to identify M-meeting points and present commuters with a range of options.

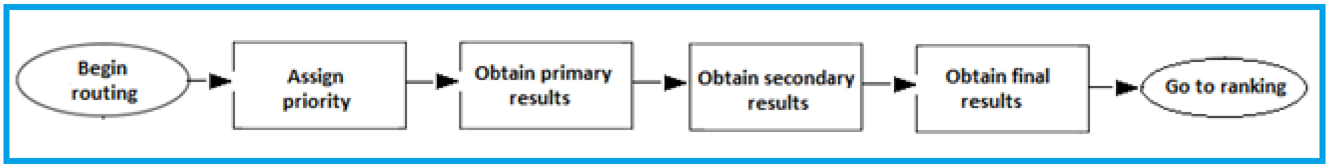


Figure 4. Routing block diagram

In addition, each shared taxi was given a priority. The shared taxis were categorized as those that traveled directly through the nodes of the commuter's destination, those that traveled through the nodes around the nodes of the commuter's destination, or those that did not travel through the nodes of the commuter's destination.

Our proposed method started by finding the arcs and nodes connecting a commuter to a shared taxi. Then, the commuter subparagraph and the shared taxi subparagraph were compared. If the arcs or nodes of the subgraphs matched, the mutual arc or node was added to the database of the shared taxi. Then, the Dijkstra algorithm was used to compute the time required to reach the intersecting points. The computed time represented the time required by the algorithm for the commuter/shared taxi to go from the current node to the meeting location. The commuters' and the shared taxi's arrival times at each meeting location were then calculated and examined. If the commuter's arrival time at the node was less than the shared taxi's arrival time, the node was deemed a valid meeting location and subsequently included in the primary findings.

A procedure of redundancy removal was implemented for secondary results. The initial sorting of the primary data collected for each shared taxi was based on the commuters' arrival times at the meeting locations. Then, an investigation was conducted of the numerous nodes and arcs required for the commuter to reach the meeting locations. If a commuter could reach the same shared taxi from two separate locations, and assuming that path A was shorter than path B, then path B was eliminated and path A's priority was adjusted accordingly.

After receiving the secondary results, a comparison of shared taxis was undertaken. In other words, if a commuter at a certain meeting location had the option to select a group of shared taxis with the same priority ranking, then these shared taxis were grouped together. This process led to the creation, examination, and archiving of the final findings.

3.5 Ranking

The purpose of this phase was to rate the findings collected during the routing phase. Priority was allocated to each ranking, which varied by mode of transportation.

In the case of unimodal transportation, data from shared taxis traveling straight to the destination or via surrounding nodes were taken into account. They were ranked according to the possibility of encountering as many shared taxis as feasible and the commuter's arrival time at the meeting location.

https://doi.org/10.5281/zenodo.6790841

In the case of multimodal transportation, a post-processing step was performed to provide the commuter with the required trip information, from the first meeting point with the first shared taxi to the second meeting point with the second shared taxi, and so on, until the commuter reached his final destination.

4. RESULTS

The results of our suggested algorithm were categorized by mode of transportation and the mode of arrival at the final destination. The outcomes were divided into three groups: direct route arrivals (Adirect), two-mode arrivals (A2mode), and one-mode two-stage arrivals (A2stage). In the first group, only shared taxis that traveled through the commuter's destination nodes were evaluated (a direct route arrival). The results were rated in ascending order based on the commuter's arrival time at the meeting point and in a decreasing order of priority; the priority was established based on the commuter’s likelihood of finding a shared taxi.

The total duration of the completed journey was determined using equation (1). This duration was given by:

$$\mathbf{duration_{total} = time_{commuter} + time_{waiting} + time_{trip}} \quad \textbf{(1)}$$

where $time_{commuter}$ represented the commuter's maximum travel time to the meeting location, $time_{waiting}$ referred to the amount of time a commuter spends waiting for a shared taxi, and $time_{trip}$ denoted the required time duration between the meeting point and the final destination.

The second category, known as "a two-mode arrival," corresponded to foot travel and the use of a shared taxi. Consideration was given to the findings received from shared taxis that did not travel through the destination but did pass through a neighboring node. The findings were ranked in ascending order by the commuter's arrival time at the meeting location and in descending order according to the importance of reaching the final destination. Equation (2) was then utilized to determine the total duration of the journey.

$$\mathbf{duration_{total} = time_{commuter} + time_{waiting} + time_{trip} + time_{walking}} \quad \textbf{(2)}$$

where $time_{commuter}$ represented the average time it took the commuter to reach the meeting point, $time_{waiting}$ denoted the time the commuter spent waiting for the shared taxi, $time_{trip}$ denoted the time taken by the commuter to travel from the meeting point to the nearest neighboring node. Furthermore, timewalking denoted the duration of travel till the final destination.

The third group, "one-mode two-stage arrival," corresponded to a trip made using two shared taxis. In this study, data acquired from shared taxis that did not pass through or travel near the commuter's final destination were disregarded.

5. EXPERIMENTATION

This section describes the algorithm's implementation and the ensuing consequences. Open Street Map was utilized in conjunction with PostgreSQL and PostGIS to obtain a geographical map of Beirut (see Figure 5). "pgRouting" was used to calculate the k-shortest pathways. As an alternative to the front-end services, QGIS was used to graphically display the results of the back-end system.

https://doi.org/10.5281/zenodo.6790841

Figure 5. Geographical map of Beirut – Lebanon

The experimental map of Beirut was a network of 1760 arcs and 1347 nodes, with the lines representing the arcs and the points representing the nodes (see Figure 6). We used the QGIS software to visualize this graph. The tracks or trajectories of fifteen shared taxis were analyzed and assigned the numbers 1001 to 1015. To build the trajectories, sites on the geographical map were identified and the shortest routes between them were then computed.

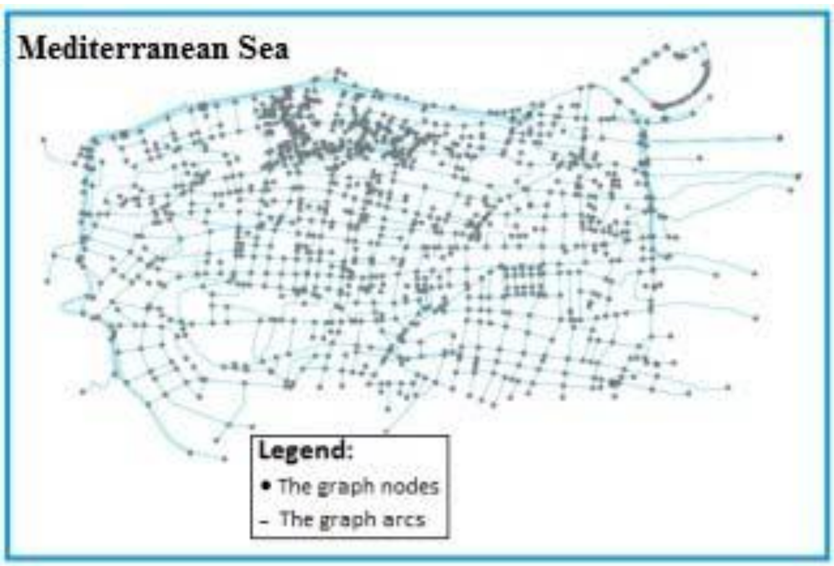


Figure 6. Constructed graph of Beirut – Lebanon

Figures 7 and 8 exhibit two-path examples for two distinct shared taxis, # 1001 and # 1002, with red circles representing current shared taxi positions, yellow squares representing the meeting points, and black lines on arcs representing the paths

https://doi.org/10.5281/zenodo.6790841

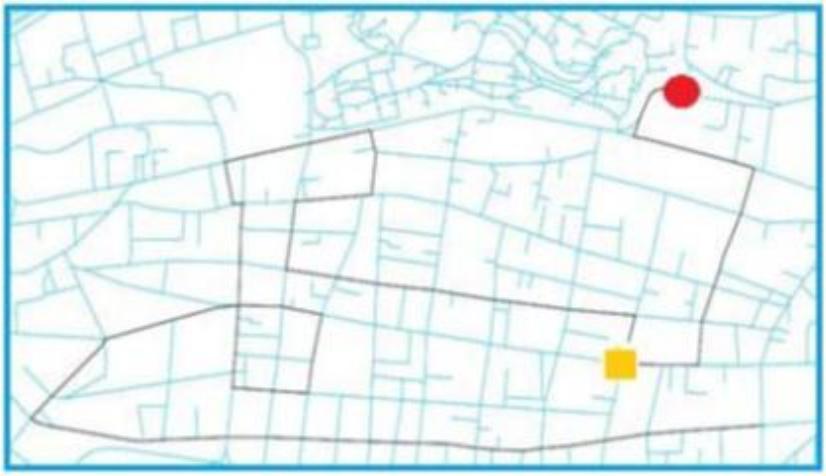


Figure 7. An example showing a shared taxi's path

Figure 8. An example showing another shared taxi's path

Each test considered various settings for the commuter's location, destination, number of shared taxis, maximum distance between the destination and neighboring nodes, and number of k-shortest paths. The ideal number of shortest paths to use while building the commuter subgraph was determined through a series of tests.

As an example, let us consider commuter 10005. This commuter is now located at (35.47936097, 33.89542295) and is on his way to his ultimate destination (35.48869691, 33.89911935). This commuter was not connected to any nodes or arcs. Therefore, a virtual node with the ID 999001 and virtual arcs were necessary. Likewise, this commuter's eventual destination was neither constrained by a node nor an arc. Therefore, a virtual node and virtual arcs were required to connect the destination nodes to the final destination.

As illustrated in Figure 9, the current location of the commuter is depicted in red (or a circle), while the destination is depicted in blue (or Rectangle). The virtual arcs are illustrated in yellow (or Squares). This figure also depicts the 100 shortest routes between the commuter's current location and the destination, as well as the locations of the drivers.

https://doi.org/10.5281/zenodo.6790841

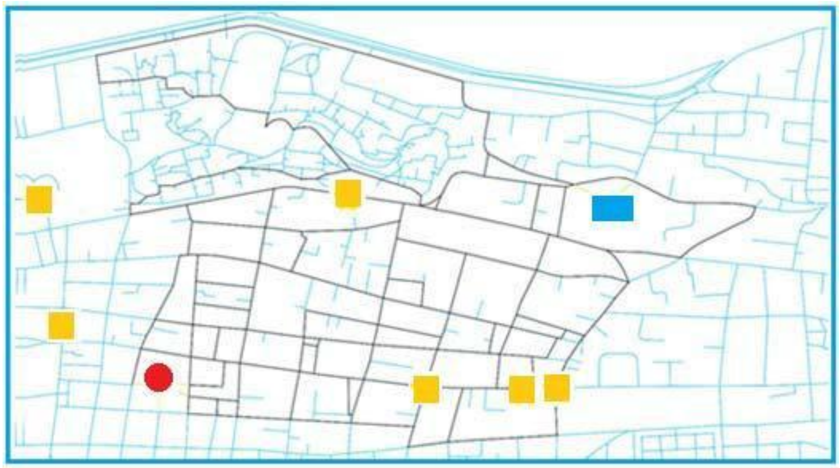


Figure 9. Commuter #10005 (his location and destination)

The values of the variables "destinationInTrajectory" and "destinationNearTrajectory", as well as the corresponding priority, are displayed in Table 2. If "destinationInTrajectory" was true, the shared taxi was travelling through the commuter's final destination. Similarly, if the "destinationNearTrajectory" attribute was true, it indicated that the shared taxi was travelling through the commuter's destination area, with nodes located 200 meters away.

Table 2. Results concerning the shared taxis corresponding to commuter #10005

The visible drivers	The number of intersecting arcs	The number of intersecting nodes	The value of the InTrajectory destination variable	The value of the NearTrajectory destination variable	The driver's priority
1001	23	19	False	False	0
1002	16	15	False	False	0
1003	65	63	True	True	100
1004	27	23	False	False	0
1005	22	20	False	True	50
1006	42	37	True	True	100
1007	22	20	False	True	50
1008	47	51	False	True	50
1010	2	1	False	False	0
1011	0	0	False	False	0
1012	22	20	False	True	50
1013	5	4	False	False	0
1014	20	18	True	True	100
1015	21	38	False	False	0

The initial phase of the algorithm (finding the primary meeting points) identified fifteen primary or valid meeting points. Following grouping and reduction of redundancy, the total number of meeting points decreased to seven. The results are summarized in Table 3. The IDs "1, 2, 3" for Shared taxi #1006 were added to Table 4's results, while the IDs "4, 5, 6" for Shared taxi #1008 were added to Table 5's results.

https://doi.org/10.5281/zenodo.6790841

Table 3. The meeting points allocated to commuter #10005

The result's ID	The meeting point	The intersecting shared taxis	Priority of the result
1	Node 635	Driver #1006	100
2	Node 531	Driver #1006	102
3	Node 738	Driver #1006	101
4	Node 90	Driver #1008	51
5	Node 379	Driver #1008	50
6	Node 1092	Driver #1008	51
7	Node 635	Driver #1001 or Driver #1004 or Driver #1010	2

Table 4. An example of recording the results in the "Adirect" table

The attributes	Their values	The attributes	Their values
psg_id	10005	**psg_time**	00:36
source_x	35.47936097	**meeting_drivers**	1006
source_y	33.89542295	**meeting_times**	01:25
destination_x	35.48869691	**directly**	TRUE
destination_y	33.89911935	**travel_time1**	03:46
path_nb	1	**hop2**	0
nodes	999001,635	**node_far**	0
edges	999001,-1	**psg_time2**	0
hop1	635	**total_time**	05:11
Comments	**Choice #1:** Commuter #10005, walk 00:36 minutes to point 635. A shared taxi will meet you there. Shared taxi #1006 will arrive in 01:25 minutes to take you to your destination. The overall duration of your trip is 05:11 minutes.		

Table 5. Results corresponding to the "A2mode"

The attributes	Their values	The attributes	Their values
psg_id	10005	**psg_time**	00:30
source_x	35.47936097	**meeting_drivers**	1008
source_y	33.89542295	**meeting_times**	02:40
destination_x	35.48869691	**directly**	False
destination_y	33.89911935	**travel_time1**	02:07
path_nb	4	**hop2**	621
nodes	999001,531,90	**node_far**	186
edges	999003,705,-1	**psg_time2**	02:13
hop1	90	**total_time**	07:00
Comments	**Choice #4:** Commuter #10005, walk 01:30 minutes to point 90. A shared taxi will meet you there. Shared taxi #1008 will arrive in 02:40 minutes to take you to 621, a nearby location to your final destination. From there, walk 186 meters to your destination; it takes roughly 02:13 minutes. The overall duration of your trip is 07:00 minutes.		

The drivers' and commuters' perspectives during the preprocessing step were eliminated after the results were determined. If m was 100, then there were no drivers in the vicinity of the commuter's destination.

https://doi.org/10.5281/zenodo.6790841

6. CONCLUSION

The fast development of digital technology has rendered no industry immune to its consequences. Businesses may contact millions of individuals simultaneously using the web platform. Regarding the ride-hailing industry, the market is currently dominated by it. Those participating in the taxi industry are cognizant of the benefits of investing in the industry. Popularity of the taxi industry can be attributed to the ease of online taxi booking and the chance to enjoy a hassle-free trip.

Regarding shared taxi applications, we believe that the shared taxi app described in this paper will, as time progresses and additional improvements are made, meet all of the commuters' criteria, given that it ensures quality and offers a fantastic commuter experience. Certainly, shared taxi drivers in Lebanon and elsewhere have difficulty communicating with commuters since they cannot track their positions. Using our shared taxi app, the commuter may now connect with the driver with a single tap on his or her cellphone screen, thereby resolving this issue. In addition, our shared taxi software ensures that fewer errors occur and that the commuter-shared taxi driver interface is completed on time. In addition, the app has safety elements, such as displaying the license plate and car model, to guarantee that commuters get into the right vehicle.

6.1 Study Limitations

Given that there are thousands of illegal shared taxis that are wandering the streets of Lebanon in general and Beirut in particular, it is possible that our App may not accurately represent the shared taxis in operation in Lebanon. In this study, only shared taxis that are registered with the Syndicate of Lebanese Taxi Drivers were included.

Because validation is an ongoing process, the authors are conducting more research to determine the most effective strategy for using our App to check its validity on a large scale with respect to future unimodal and multimodal transportation.

6.2 Future Possibilities

In terms of the lack of credible and valid methods for obtaining data on the perceptions of shared taxi drivers in Lebanon, the current study has filled in certain gaps in the literature. Certainly, it is the first of its kind in Lebanon. As with anything novel, there are entry obstacles. It is essential to recognize and deal with the reality of the road ahead. Some obstacles include:

- PCT is primarily intended for urban environments. Due to the illegal shared taxis that are wandering the streets of Lebanon's suburbs and rural areas, PCT may not function well there. This means that residents of these areas will require alternative modes of transport.

- PCT is intended to be used via a mobile application. It is feasible that a commuter portal for booking trips on a computer may become available, but the premise of PCT is that transportation access is portable and on-demand. Not everyone will have access to or desire to arrange vacations using mobile devices.

- Transportation agencies function autonomously. If transportation systems continue to function in silos, coordination of services for commuters across service areas will grow more challenging. Commuters will gain the most from multimodal transportation if transit agencies collaborate about infrastructure and pooled resources.

https://doi.org/10.5281/zenodo.6790841

ACKNOWLEDGMENT

This project was supported by Agence Universitaire de la Francophonie (AUF-BMO) within the framework of Interuniversity Scientific Cooperation Projects - ePTC.

REFERENCES

Ayed, H., Galvez-Fernandez, C., Habbas, Z. and Khadraoui, D. (2011). "Solving time-dependent multimodal transport problems using a transfer graph model". Computers and Industrial Engineering, Vol. 61, Issue 2, pp. 391-401.

Choueiri, E., Choueiri, G.M., & Choueiri, B.M. (2015). Road Safety in Lebanon: Magnitude, Cost and Potential Countermeasures. Advances in transportation studies, 35.

Cole, M. (2018). Mobility as a Service: Putting transit front and center of the conversation. CUBIC Transportation Systems.

Dib, O., Manier, M.A. and Moalic, L. (2016). "Advanced Modeling Approach for Computing Multicriteria Shortest Paths in Multimodal Transportation Networks". IEEE International Conference on Intelligent Transportation Engineering, pp. 40-44.

Eppstein, D. (1998). Finding the k Shortest Paths. SIAM J. Comput., 28, 652-673.

Fiorenzo-Catalano, M.S. (2007). "Choice Set Generation in Multi-Modal Transportation Networks". Delft: TRAIL Research School, pp. 38-39.

Flórez, J.E., Torralba, Á., García, J., López, C.L., Garcia-Olaya, A., & Borrajo, D. (2011). Planning Multi-Modal Transportation Problems. ICAPS.

Garcia, J., Torralba, A., Gracia-Olaya, A., Florez, J.E. and Borrajo D. (2012). "Solving Multi-modal and Uni-modal Transportation Problems through TIMIPlan". IFAC Proceedings Volumes, Vol. 45, Issue 24, 203-208.

Hassine, I., & Canalda, P. (2015). CIMO: An efficient 2-phases calculator of multimodal itineraries for real trans-territories based on dynamic programming. 2015 World Congress on Information Technology and Computer Applications (WCITCA), pp. 1-11.

Hedi, A., Habbas, Z., Galvez-Fernandez, C. and Khadraoui D. (2009). "Hybrid Algorithm for Solving a Multimodal Transport Problems Using a Transfer Graph Model". Proceeding GIIS'09 Proceedings of the Second international conference on Global Information Infrastructure Symposium, pp. 385-390.

Mahi, F., Nait-Sidi-Moh, A., Debbat, F. and Khelfi M.F. (2012). "A Multimodal Transportation System: Hybrid Petri Net-based Modeling and Simulation". IEEE International Conference on Complex Systems, 1-6.

Martins, E., & Pascoal, M. (2003). A new implementation of Yen's ranking loopless paths algorithm. 4OR: Quarterly Journal of the Belgian, French and Italian Operations Research Societies, 1(2), pp. 121–133.

National Center for Mobility Management (MCMM) (2018). Mobility as a Service: Concept and Practice.

Santos, J. L. (2007). "K-Shortest Path Algorithms". Centro de Matemática da Universidade de Coimbra, 1-14.

Tsolkas, D., Passas, N.I., Xenakis, C., Papataxiarhis, V., & Tsetsos, V. (2012). Busfinder: A Personalized Multimodal Transportation Guide with Dynamic Routing. 2012 16th Panhellenic Conference on Informatics, pp. 25-30.

'GitHub - pgRouting/osm2pgrouting: Import tool for OpenStreetMap data to pgRouting database'. Available at: https://github.com/pgRouting/osm2pgrouting/

'OpenStreetMap Wik'. Available at: https://wiki.openstreetmap.org/wiki/

'pgRouting Project – Open-Source Routing Library'. Available at: https://pgrouting.org/index.html.

'PostGIS -- Spatial and Geographic objects for PostgreSQL'. Available at: https://postgis.net

'PostgreSQL: The World's Most Advanced Open-Source Relational Database'. Available at: https://www.postgresql.org/

'Welcome to the QGIS project'. Available at: https://qgis.org/en/site/

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

WSO National Office for Algeria
c/o Institut des Sciences et de la Technologie (I.S.T.)
attn.: Mr. Ferhat Mohia, Director
contact: ferhatmohia@yahoo.fr

WSO National Office for Australia
c/o Curtin University of Technology
attn.: Dr. Janis Jansz, Director
contact: j.jansz@curtin.edu.au

WSO National Office for Austria
c/o Payesh System Mehr Engineering Company
attn.: Dr. Majid Alizadeh, Director
contact: majidealizadeh@gmail.com

WSO National Office for Cameroon
c/o Cameroon Safety Services
attn: Mr. Clement B. Nyong, Director
contact: ny.clement@yahoo.com

WSO National Office for Canada
c/o Apex One Management Group
attn.: Mr. Michael Brown, Director
contact: michael.brown@worldsafetycanada.ca | mike@apexone.com
website: worldsafetycanada.ca

WSO National Office for Ghana
c/o Ghana National Fire Service
attn.: Mr. Peter Oko Ahunarh, Director
contact: pahunarh23@gmail.com

WSO National Office for India
c/o Indian Society of Safety Engineers (I.S.S.E)
attn.: Mr. T. Shankar, Director
contact: support@worldsafety.org.in

WSO National Office for Indonesia
c/o Prosafe Institute
attn.: Mr. Soehatman Ramli, Director
contact: soehatmanramli@yahoo.com

WSO National Office for Iran
c/o Payesh System Mehr Engineering Company
attn.: Mrs. Fatemeh Gilani, Director
contact: gilani@imsiran.ir

WSO National Office for Iraq
c/o NAYA Engineering Services & Training
attn.: Dr. Eng. Khaldon Waled Suliman, Director
contact: naya_engineering_services@yahoo.com

WSO National Office for Lebanon
c/o Ministry of Transport
attn.: Dr. Elias M. Choueiri, Director
contact: elias.choueiri@gmail.com

WSO National Office for Myanmar
c/o Win Oshe Services Co., Ltd
attn.: Mr. Win Bo, Director
contact: winbo@osheservices.com

WSO National Office for Nigeria
c/o DanaRich Creative Concept, LTD
attn.: Mr. Soji Olalokun, WSO-RSD, Director
contact: info@worldsafety.org.ng
website: worldsafety.org.ng

WSO National Office for Pakistan
c/o Greenwich Training & Consulting
attn.: Mr. Tayyeb Shah, Director
contact: doctimes@gmail.com

WSO International Office for Philippines
attn.: Engr Alfredo A. De La Rosa Jr., Director
contact: info@wsophil.org

WSO National Office for Saudi Arabia (KSA)
c/o The Academy of Sciences for Medical Education
attn.: Mr. Rocky Binuya, Director
contact: info@aos-ksa.com | binuya.rocky@gmail.com
website: https://aos-ksa.com/en

WSO National Office for United Arab Emirates (UAE)
c/o Tatweer Industrial Inspection & Training Services LLC
attn.: Miss Nazya Robin, Quality Manager & Director
contact: info@tiits.ae

WSO National Office for Vietnam
c/o Safety Training & Consulting Limited
attn.: Mr. Binh Pham, WSO-CSI(ML), Director
contact: binh.pt@worldsafety.org.vn
binh.pt@safety.edu.vn
website: worldsafety.org.vn

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."

Published by the WSO National Office for Lebanon
www.worldsafety.org
info@worldsafety.org | elias.choueiri@gmail.com