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# Applying systems thinking to improve the safety of work-related drivers: A systematic review of the literature

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ABSTRACT

*Introduction:* Light vehicles (<4.5 tons) driven for work purposes represent a significant proportion of the registered motor vehicles on our roads. Drivers of these vehicles have significant exposure to the dangers of the road transport environment. To optimize safety for these workers, it is critical to understand the factors contributing to risk of being involved in an incident. This information can then be used to inform the review and revision of existing risk controls and the development of targeted prevention activities. *Method:* The aim of the study was to undertake a systematic review of the literature to identify the factors associated with work-related driving incidents. The factors identified in the review were represented within an adapted version of Rasmussen's risk management framework (Rasmussen, 1997). Fifty studies were analyzed following data screening and review of full text. The highest proportion of risk factors were categorized at the lower levels of the system, including the 'Drivers and Other Road Users' level (n = 20, 44.4%) and the 'Equipment, Environment, and Meteorological Surroundings' level (n = 19, 42.2%). There were no risk factors identified at the 'Regulatory and Government Bodies' levels of the framework, confirming the narrow investigative scope of past research and the need to acknowledge a broader range of factors within and across higher levels of the system. *Conclusions:* The findings of this study inform the direction of future research and design of targeted prevention activities capable of creating system change for the safety of work-related drivers.



## 1. Introduction

Road freight is a safety critical industry and has the highest death rate of its employees compared to that of other industries (Safe Work Australia, 2018). While much research has focused on vehicles over 4.5 tons, smaller vehicles (e.g., passenger vehicles, utility vans) also represent a significant public health issue. However, limited attention has focused in this area given the challenges associated with collecting data on the 'purpose of the journey' of a road traffic incident (i.e., work or personal purposes; Newnam et al., 2014). Regulators do not routinely collect data specifying whether a crash occurred when driving for work or personal purposes.

Despite this, prevention activities are emerging to manage the risks associated with those who drive a light vehicle for work-related purposes. In Australia, vehicles driven for work purposes represent 30% of the registered motor vehicles in Australia, with some drivers reporting travelling over 1,100 kilometers per week (Zurich Insurance, 2015). The risk associated with exposure to the road transport environment is evidenced, globally. To illustrate, a total of 1,270 U.S. workers driving or riding in a motor vehicle for work-related purposes on a public road died in 2019 (representing 24% of all work-related deaths; NIOSH, 2022). Moreover, 56% of these workers who died were not employed in a motor-vehicle operator job; rather, driving was considered a secondary task to their primary job role (e.g., in-home nursing care, sales representatives; Newnam, Lewis, & Watson, 2012). This issue creates some challenges in managing the safety and balancing tensions with competing priorities (i.e., efficiency and productivity).

Managing the safety of these workers is further challenged because, unlike the road freight transport industry, a 'Chain of Responsibility' does not exist for managing the safety of workers who operate a light vehicle. Thus, there is limited guidance in the roles and responsibilities of those responsible for managing the safety of workers that operate a light vehicle, beyond what is specified in Occupational Health and Safety legislation. The complexity of this issue is compounded when there is no single government body or department responsible for managing the allocation of resources for road safety outcomes or are tasked with managing data and monitoring road safety issues (Newnam & Muir, 2021). This is even the case in countries where the national road safety

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strategy and associated legislation has adopted the Safe System concept, such as Australia (Muir, Johnston, & Howard, 2018). Given the sheer number of stakeholders capable of influencing change within this dynamic environment, and no central point of responsibility, it is not surprising that limited lessons and evidence-based best practice approaches specific to driving light vehicles for work-related purposes have been established for preventing associated road safety incidents.

Indeed, the lack of ability to learn from crashes or near crashes is a critical barrier to improving the safety of this workforce. Warmerdam et al. (2017) interviewed employees across 79 workplaces that employ individuals to drive a light vehicle for work-related purposes across two states in Australia and identified that few have practices in place for investigating incidents involving a work vehicle. Rather, incidents (e.g., crashes or near crashes) involving a light vehicle are investigated by the companies that insure the vehicle, not the employer. The limitation with this approach is that motor-vehicle insurers use a narrow investigative scope, as a driver interview is used as the primary source of information. This means that investigations are focused mainly on the role of the driver and their actions at the time of the crash. Drivers are often given little reason or opportunity to reflect upon any organizational or external factors that may contribute to crashes, such as vehicle maintenance, scheduling, and regulatory restrictions. Furthermore, there is often limited consultation with other key stakeholders in the system (e.g., fleet managers, supervisors; Newnam, Griffin, & Mason, 2008) that could provide insight into the broader system of factors that contributed to risk in any work-related driving incident.

Historically, crash investigation for heavy vehicle crashes has been described as insufficient for learning and developing appropriate control measures (Newnam & Goode, 2015; Newnam, Warmerdam, Sheppard, Griffin, & Stevenson, 2017), and as such, there is also little substantive learning for light vehicles that can be transferred from investigation processes undertaken in the road freight transport industry. Again, these investigations primarily focus on driver-level factors such as driver characteristics (e.g., age, gender) and behavior (e.g., inappropriate speed, fatigue, and drug use). These types of toolkits imply drivers are to "blame" for crashes, ignoring the broader system of factors influencing crash involvement.

The lack of systematic and rigorous investigation of system and organizational-level circumstances of individual crash incidents involving light or heavy vehicles is an impediment to progressing the safety improvements needed to ensure worker and public safety on roads. Reductionist-focused incident investigation models and methods have also been identified as inadequate across other safety critical industries, including healthcare (Newnam, Goode, Read, & Salmon, 2020; Newnam, Goode, Read, Salmon, & Gembarovski, 2021). More consistent with current thinking, a systems-thinking approach (Rasmussen's risk management framework and the associated Accimap technique; Rasmussen, 1997) is required as a first step to better understand these incidents, followed by a review and revision of existing risk controls to develop feasible, effective, and practicable control measures.

In other high-risk industries (e.g., healthcare), systems-thinking models and analysis methods now represent an accepted approach for optimizing safety activities (Cassano-Piche, Vicente, & Jamieson, 2009; Goode, Salmon, Lenne, & Finch, 2018; Hulme, Stanton, Walker, Waterson, & Salmon, 2019; Newnam et al., 2020; Newnam et al., 2021). These models and methods are underpinned by the idea that incidents occur due the interaction between multiple factors across a system (Leveson, 2011; Rasmussen, 1997). The behavior of the individual-worker, the equipment used to complete the work task, and the safety practices of employers are only some of the factors that need to be considered in an incident investigation. To illustrate this type of investigation tool, Newnam et al. (2020) developed the Patient Handling Injuries Review of Systems (PHIRES) tool to help guide practitioners in the healthcare sector in a system-thinking investigation following the report of a musculoskeletal injury to staff associated with patient handling. The tool is underpinned by the systems-thinking approach, Rasmussen's Risk Management framework, and the associated Accimap technique (Rasmussen, 1997; Svedung & Rasmussen, 2002). The multiple work systems, represented as hierarchical levels, were adapted in the PHIRES tool to represent the healthcare system. A classification scheme was developed to describe the work-related and societal factors, in addition to the physical factors, typically associated with increased risk relating to the work task of patient handling, and subsequently represented at each level of the healthcare system. These factors were identified through a systematic review of the literature and in consultation with key stakeholders in the industry.

Thus, there is much that can be learned from previous research to move toward improved prevention of work-related driving incidents. Systems thinking models (i.e., Rasmussen's risk management framework (1997) are needed to best understand the factors associated with the risk of work-related driving incidents. The first step in creating systemic change in prevention activities is to identify the range of factors contributing to work-related driving incidents. Such an approach is critical to move beyond the current reductionist thinking and towards a more comprehensive understanding of the system of factors contributing to crashes. Improving the capture of data related to risk in work-related driving will inform the development of targeted prevention activities, including creating a culture where responsibility for safety is shared across the system.

The aim of the current study is to undertake a systematic review of the literature to identify the system of factors associated with work-related (light or heavy) vehicle driving incidents. The factors identified in the review will be represented on Rasmussen's risk management framework (Rasmussen, 1997). This framework has been adapted to align with the typical system that employs individuals that operate a vehicle for work-related purposes and has also drawn upon learnings from the road freight transportation system (Newnam, Goode, Salmon, & Stevenson, 2017). The five levels of the system are described in Table 1.

## 2. Method

A systematic review of the literature was undertaken, guided by PRISMA guidelines, to identify factors contributing to work-related driving incidents, which were defined as crashes and near crashes (i.e., near misses). A comprehensive list of search terms was developed to guide the search using the categories: (i) *primary context*, including workplace (i.e. workplace, work-related, occupation*, vocation*, professional) AND driving (driv*, transport, fleet, vehicle*, commercial), AND injury/incident (injur* (NOT chemical), safety, risk); (ii) *outcome* focused terms (e.g. crash*, accident*, ticket*, fine*, penalty, infringement*, near miss*, loss of control); and (iii) *Other* terms to help to limit/refine the scope of the literature to papers with a focus on factors contributing to such incidents (e.g. caus*, contrib*, predict*, risk factor*, determin*, predict*).

The search was restricted to journal articles published from 2010 through 2021. Six databases were used to conduct the search (Medline, PubMed, AMED, Scopus, PsycINFO and Web of Science). Studies that identified the relationship between work-related driving crashes for *both light and heavy vehicles* were included to expand the scope of knowledge.

**Table 1**
Hierarchical levels of the system of factors contributing to work-related vehicle incidents (adapted from Rasmussen's Risk Framework, 1997).

| | |
|---|---|
| Government, Regulators & External Influences | Factors external to the organization relating to laws governing safe working practices. This level also considers factors associated with external influencers (media reporting, social media, community attitudes). |
| Governance & Administration | Factors associated with personnel working for companies, as well as policies and guidelines that regulate work practices. |
| Operations Management | Factors associated with the employer and different levels of management personnel (e.g., supervisor, fleet manager). Factors at this level typically occur prior to the incident but can also include decisions and actions made during, or in response to, the incident. Contributory factors related to policy, planning and budgeting typically occur well before the crash itself, and may even exist years before the crash occurred. |
| Drivers & Other Road Users | Factors contributing to the incident prior to, and during, the crash. This level includes factors related to actors directly involved in the operation of the vehicle (including passengers) as well as other actors at the scene of the crash (e.g. other drivers). |
| Equipment, Vehicle & Surrounding Environment | Factors associated with the vehicle and equipment (e.g., in-vehicle telemetry), the physical road environment (e.g., road surface conditions), and the ambient and meteorological conditions prior to or during the crash. |

The search strategy is outlined in Fig. 1. The initial search resulted in 346 articles that were imported into EndNote. Duplicates were then identified and deleted (n = 183), leaving 163 articles that were examined in the title and abstract screening stage. Two authors (AS, RS) independently screened approximately 60% of the titles and abstracts (n = 98) for potentially relevant articles, and reached 97% agreement. A third author (SN) made the final decision for the remaining three titles and abstracts. One author (RS) completed the title and abstract screening for the remaining 65 articles. The title and abstract screening stage resulted in the exclusion of 100 articles for reasons including that the study was not focused on work-related driving, no risk factors were identified, or the outcome variable was not relevant to crashes or crash risk. Sixty-three articles were retained for the full text stage. These articles were independently reviewed by two authors (AS, RS), resulting in 95% agreement. A third author (SN) made the final decision for the remaining three articles. Thirteen articles were excluded during this stage (see reasons for exclusion in Fig. 1), resulting in 50 articles being retained for the data extraction stage.

Data extracted from each of the 50 articles in the final sample included: industry; country/region in which the study was conducted; employee cohort; outcome variables; and risk factors (mapped onto systems thinking classification scheme). Consistent with the aim of this study, all risk factors identified in the articles were categorized at a level of the system irrespective of the quality of the study or statistical significance with the outcome variable.

## 3. Results

Of the 50 articles included in this review, the most common industries represented were road freight transportation (n = 18, 36.0%) and farming/agriculture (n = 10, 20.0%). The taxi and bus industries each accounted for 14.0% of the articles included (n = 7 each), followed by emergency services (n = 4, 8.0%), delivery riders (n = 2, 4.0%), and mining (n = 1, 2.0%). There were four articles (8.0%) that did not specify a particular industry. Note that the total sum by industry is greater than 50 due to some articles including more than one industry type. The employee cohort in each study consisted of a combination of light and heavy vehicle employees driving for work-related purposes within the aforementioned

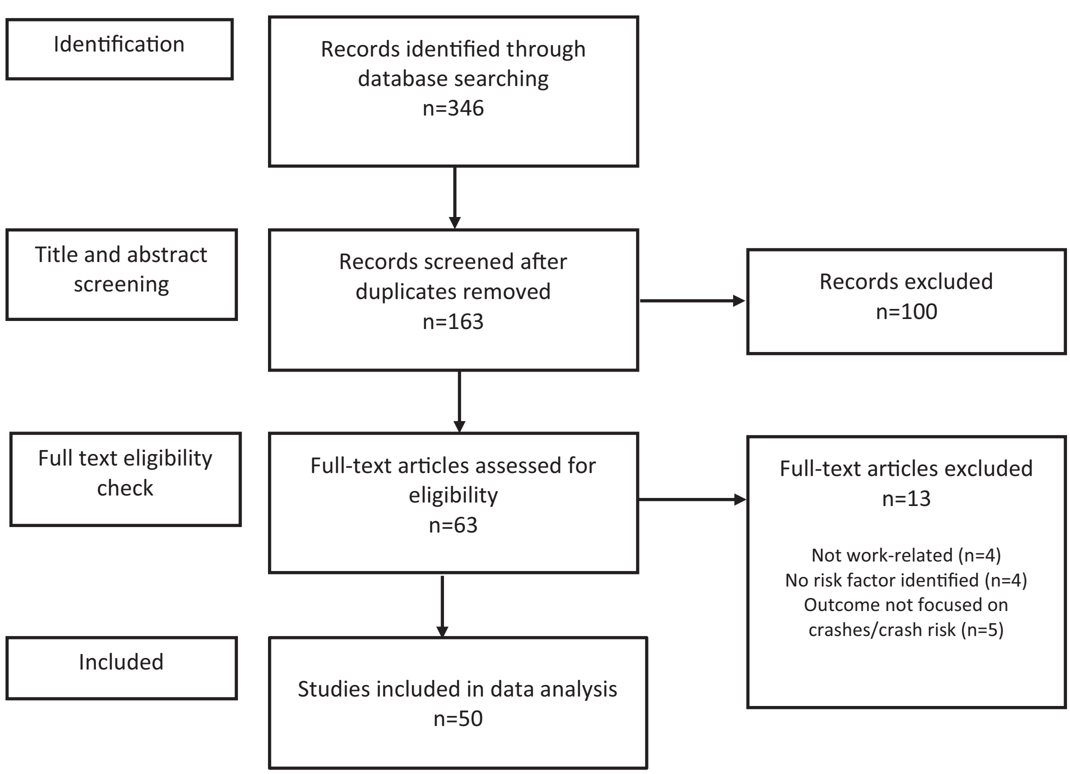


**Fig. 1.** Flow chart of the systematic search.

industries (e.g., road freight drivers, farmers, bus drivers), and emergency services (i.e., police officers, firefighters, and ambulance drivers).

The largest proportion of studies were from the United States (n = 19, 38.0%). The remaining articles represented diverse countries/regions around the world including Asia (n = 15, 15.0%), Australia/New Zealand (n = 6, 12.0%), Europe (n = 3, 6.0%), Iran (n = 3, 6.0%), Africa (n = 2, 4.0%), and South America (n = 2, 4.0%).

A work-related driving incident was the outcome of interest when conducting the search. As such, dependent variables included crashes (n = 29, 58.0%), injury severity (n = 8, 16.0%), crash risk (n = 6, 12.0%), near crashes (n = 5, 10.0%), loss of control events (n = 3, 6.0%), unsafe driver actions (n = 1, 2.0%) and aberrant driving behavior (n = 1, 2.0%).

A total of 45 risk factors were identified by the systematic review. Each risk factor was mapped onto the relevant level of an adapted version of Rasmussen's risk management framework (Rasmussen, 1997). Table 2 shows that the highest proportion of risk factors were categorized at the Drivers and Other Road Users level (n = 20, 44.4%), followed closely by risk factors at the Equipment, Environment, and Meteorological Surroundings level (n = 19, 42.2%). There were no risk factors identified at the Government, Regulatory and External Influencers level of the framework.

A description of the risk factors identified at the three lower levels of the system follows (with associated reference). The risk factors are sub-categorized and the corresponding articles in which the risk factors were identified are referenced. The number of risk factors identified within each article ranged from one to eight. Across all levels of the system, the most commonly cited risk factors were road design (n = 13), fatigue/sleepiness (n = 11), and traffic violations (previous history) (n = 10).

Table 3 shows the risk factors (n = 19) identified at the Equipment, Environment and Meteorological Surroundings level. This level encompasses a range of factors related to features and design of the vehicle (n = 8 risk factors), the road environment the time of year (n = 8 risk factors) and meteorological conditions (n = 3 risk factors). Risk factors categorized as 'Environment' were identified in the greatest number of articles overall at this level. Road design (n = 13), time of day/week (n = 8), and road surface conditions (n = 6) were the most commonly identified risk factors across the articles at this level.

Table 4 describes the risk factors identified at the Drivers and Other Road Users level. This level encompasses a broad range of factors related to the safe operation of the vehicle by the driver, (n = 17 risk factors) including several factors related to the physical and mental state of the driver (n = 1 risk factors), as well as design of the work environment (n = 2 risk factors). Seventeen risk factors were categorized within the category of Driver and represented the greatest number of articles overall at this level. Fatigue (n = 11), traffic violations (n = 10), and driving behavior (n = 9) were identified as risk factors in the greatest number of articles within this level of the system. Physical/medical condition (n = 8) and driver experience/competence (n = 6) were also frequently cited risk factors contributing to work-related driving incidents.

Table 5 describes the risk factors identified at the Companies and Employers level and encompassed a range of factors related to leadership (n = 2 risk factors) and work scheduling (n = 4 risk factors). Rostering (i.e., assignment of employees to a duty schedule; work scheduling, n = 7) was the most frequently identified risk factor across all articles at this level; however, several articles that identified rostering as a risk factor also identified another risk factor at this level. This manifests as an overlap of articles for these risk factors and demonstrates that these factors are likely closely related to each other. Leadership includes two risk factors that are related to the culture of the workplace, including organiza-

**Table 2**
Risk factors categorized at the three levels of the framework.

| Level | Number of Risk Factors | % |
|---|---|---|
| Equipment, Environment and Meteorological Surroundings | 19 | 42.2 |
| Drivers and Other Road Users | 20 | 44.4 |
| Operations Management | 6 | 13.4 |
| Governance and Administration | 0 | 0 |
| Government, Regulators & External Influences | 0 | 0 |

**Table 3**
Risk factors identified at the Equipment, Environment, and Meteorological Surroundings level.

| Level of system | Risk factors |
|---|---|
| Equipment | Lack of warning signals (Missikpode, Peek-Asa, Young, & Hamann, 2018; Wang, Zhang, Li, & Liang, 2019) |
| | In-vehicle technology (Stevenson et al., 2014) |
| | Vehicle specifications (Chen & Zhang, 2016; Lemp, Kockelman, & Unnikrishnan, 2011) |
| | Design of vehicle (Haq, Zlatkovic, & Ksaibati, 2020; Milosavljevic et al., 2011) |
| | Lack of maintenance (Wang & Prato, 2019) |
| | Road signage (Chu, 2012, 2016; Mehlhorn, Wilkin, Darroch, & D'Antoni, 2015; Ramirez et al., 2016) |
| | Load/storage (Lemp et al., 2011; Shipp, Vasudeo, Trueblood, & Garcia, 2019; Stevenson et al., 2014) |
| | Lack of or inappropriate personal protective equipment (Mitchell, Bambach, & Friswell, 2014) |
| Meteorological surroundings | Lighting (Haq et al., 2020; Lemp et al., 2011; Ramirez et al., 2016; Useche, Cendales, Alonso, & Montoro, 2020) |
| | Weather conditions (Chen & Zhang, 2016; Chu, 2016; Das, Islam, Dutta, & Shimu, 2020; Haq et al., 2020; Lemp et al., 2011; Mehlhorn et al., 2015; Missikpode et al., 2018; Stevenson et al., 2014; Wang & Prato, 2019; Wang, Zhang, et al., 2019) |
| | Visibility (Chen & Zhang, 2016) |
| Environment | Road surface conditions (Besharati & Kashani, 2018; Chen & Zhang, 2016; Milosavljevic et al., 2011; Missikpode et al., 2018; Mitchell et al., 2014; Useche, Cendales, Alonso, & Montoro, 2020) |
| | Urban/rural (Chu, 2012; Das et al., 2020; Harland, Bedford, Wu, & Ramirez, 2018; Missikpode et al., 2018; Mitchell et al., 2014) |
| | Road furniture (Chu, 2012; Mehlhorn et al., 2015) |
| | Time of day/week (Chen & Zhang, 2016; Das et al., 2020; Harland et al., 2018; Mehlhorn et al., 2015; Useche, Cendales, Alonso, & Montoro, 2020; Wang & Prato, 2019; Zhang et al., 2017; Zuzewicz, Konarska, & Luczak, 2010) |
| | Traffic congestion (Das et al., 2020; Lemp et al., 2011) |
| | Season of the year (Chen & Zhang, 2016; Zhang et al., 2017) |
| | Road design (Carman et al., 2010; Chen & Zhang, 2016; Chu, 2012; Das et al., 2020; Gorucu, Murphy, & Kassab, 2017; Haq et al., 2020; Lemp et al., 2011; Mehlhorn et al., 2015; Missikpode et al., 2018; Mitchell et al., 2014; Ranapurwala, Mello, & Ramirez, 2016; Stuckey, Glass, LaMontagne, Wolfe, & Sim, 2010; Wang & Prato, 2019) |
| | Speed limit (Chu, 2012, 2016; Das et al., 2020) |

**Table 4**
Risk factors identified at the Drivers and Other Road Users level.

| Level of system | Risk factors |
|---|---|
| Work design | Job demands (Mamo, Newnam, & Tulu, 2014; Useche, Cendales, Alonso, & Orozco-Fontalvo, 2020; Zheng, Ma, Guo, Cheng, & Zhang, 2019) |
| | Safety culture (Mamo et al., 2014) |
| Drivers | Aggression (Harland et al., 2018; Lemp et al., 2011; Wang, Zhang, et al., 2019) |
| | Inattention/distractions (Chu, 2016; Harland, Carney, & McGehee, 2016) |
| | Alcohol/drugs (Haq et al., 2020; Harland et al., 2018; Lemp et al., 2011; Mitchell et al., 2014; Newnam, Blower, Molnar, Eby, & Koppel, 2018) |
| | Personality traits (Clay, Treharne, Hay-Smith, & Milosavljevic, 2014; Mallia, Lazuras, Violani, & Lucidi, 2015) |
| | Safety attitudes (Nickenig Vissoci et al., 2020; Sun & Tian, 2018) |
| | Physical/medical condition (Anderson et al., 2012; Barger et al., 2015; Besharati & Kashani, 2018; Das et al., 2020; Haq et al., 2020; Milosavljevic et al., 2011; Thiese et al., 2017; Zhang et al., 2017) |
| | Driving behaviour (Ba, Zhou, & Wang, 2018; Chen & Zhang, 2016; Chu, 2012; Nickenig Vissoci et al., 2020; Shams, Mehdizadeh, & Khani Sanij, 2020; Shin, Park, & Jeong, 2018; Useche, Cendales, Alonso, & Orozco-Fontalvo, 2020; Wang, Li, & Prato, 2019; Zuzewicz et al., 2010) |
| | Experience/competence (Carman et al., 2010; Chen & Zhang, 2016; Stevenson et al., 2014; Wang & Prato, 2019; Zheng et al., 2019; Zuzewicz et al., 2010) |
| | Hazard perception skill (Besharati & Kashani, 2018; Sun & Tian, 2018) |
| | Seat belt (Haq et al., 2020; Newnam et al., 2018; Shipp et al., 2019; Stuckey et al., 2010) |
| | Drugs/medication (Ogeil et al., 2018; Reguly, Dubois, & Bedard, 2014) |
| | Risk perceptions (Clay et al., 2014; Shams et al., 2020; Zheng et al., 2019) |
| | Mobile phone use (Ba et al., 2018) |
| | Fatigue/Sleepiness (Ba et al., 2018; Besharati & Kashani, 2018; Chen & Zhang, 2016; Haq et al., 2020; Kim, Jang, Kim, & Lee, 2018; Mitchell et al., 2014; Shin et al., 2018; Stuckey et al., 2010; Wang, Li, et al., 2019; Wang, Zhang, et al., 2019; Zhang et al., 2017) |
| | Traffic violations (Chu, 2012, 2016; Mallia et al., 2015; Mehdizadeh, Shariat-Mohaymany, & Nordfjaern, 2019; Nik Mahdi, Bachok, Mohamed, & Shafei, 2014; Reguly et al., 2014; Shams et al., 2020; Shipp et al., 2019; Wang, Zhang, et al., 2019; Zhang et al., 2017) |
| | Speed (Chu, 2016; Milosavljevic et al., 2011; Mitchell et al., 2014; Newnam et al., 2018; Stuckey et al., 2010) |
| | Sleep quality (Nik Mahdi et al., 2014; Shams et al., 2020) |
| Other road users | Behavior: general (Gorucu et al., 2017; Shipp et al., 2019) |

**Table 5**
Risk factors identified at the Operations Management level.

| Level of system | Risk factors |
|---|---|
| Leadership | Mental health/wellbeing/OHS (Baba, Miyama, Sugiyama, & Hitosugi, 2019; Sun & Tian, 2018) |
| | Safety culture (Sun & Tian, 2018) |
| Work scheduling | Rostering (Besharati & Kashani, 2018; Kim et al., 2018; Mehdizadeh et al., 2019; Nik Mahdi et al., 2014; Torregroza-Vargas, Bocarejo, & Ramos-Bonilla, 2014; Wang & Wu, 2019; Zheng et al., 2019) |
| | Shift work (Besharati & Kashani, 2018; Ogeil et al., 2018; Stevenson et al., 2014; Wang & Wu, 2019) |
| | Breaks (Baba et al., 2019; Chen & Xie, 2014; Stevenson et al., 2014; Torregroza-Vargas et al., 2014) |
| | Workload (Ba et al., 2018; Wang, Li, et al., 2019; Zheng et al., 2019) |

tional policies regarding health, safety, and wellbeing of employees within the company.

## 4. Discussion

This goal of this study was to establish a systems-perspective evidence-base to better understand the range of factors contributing to work-related vehicle driving incidents. This goal was achieved through undertaking a systematic review of the literature to identify the factors contributing to incidents using a systems perspective. To do this, the factors identified in the systematic review were mapped onto Rasmussen's Risk Management framework (1997). The findings of this study address a gap in current knowledge of the system of factors contributing to work-related driving incidents. This information is important to inform the direction of future research and design of targeted prevention activities.

This study found that most factors were identified at the 'Drivers and Other Road Users' and 'Equipment, Environment and Meteorological Surroundings' levels. This finding is not surprising considering that existing data collection methods use a narrow investigative scope, focusing primarily on the actions of the driver, the vehicle, and the immediate environment surrounding the incident. While it is critical to capture this information, it is equally as important to acknowledge a broader range of factors within and across other levels of the system that have contributed to the likelihood of the crash, potentially in the weeks or months leading up to the work-related driving incident.

To illustrate, there is research to support the argument that a work-related drivers' engagement in inappropriate speed is influenced by higher-level factors such as work pressure (Newnam, Greenslade, Newton, & Watson, 2011), organizational systems and practices (Newnam, Warmerdam, et al., 2017), and the priority and value given to safety in the workplace (or lack thereof; Newnam et al., 2008). Many of these middle-level factors were identified in the results of this study. However, there were no risk factors identified at the Regulatory and Government Bodies levels of the framework. We know that in some countries (i.e., Australia, South Africa, Canada, New Zealand) that responsibility for safety has been allocated to actors at these higher levels for some forms of transportation; for example, Chain of Responsibility legislation in Australia is used to define the roles and responsibilities of actors involved in the heavy vehicle road transport system. Addressing this gap in scientific knowledge presents an opportunity for future research to better understand the influence of regulatory and government bodies in light vehicle work-related driving incidents and areas where they can mitigate risk and improve consultation across levels of the system.

This learning could be achieved through development of a system thinking incident investigation tool designed to guide practitioners in identifying risk factors associated with work-related driving crashes. As established in previous research (Newnam et al., 2020; Newnam et al., 2021), such a tool would provide a comprehensive and standardized approach to identifying targeted prevention activities and creating a shared responsibility for safety across the system; that is, prevention activities focused beyond the lower levels of the system and focused on creating systemic change as opposed to isolated change to individual elements of the system (e.g., speed enforcement). It is also possible that the findings from this tool could be used to develop Chain of Responsibility legislation for the use of light work-related vehicles.

## 5. Limitations

A potential limitation of the current study is that the systematic review did not include a review of the grey literature. We have learned through the development of system thinking investigation tools (Newnam et al., 2020, 2021) that there are factors at other levels of the system not yet identified in the academic literature due to the historically narrow focus. Thus, future research should ensure that the findings of this study are supplemented with information gained through a scan of the grey literature, as well as knowledge from subject matter experts, to provide a comprehensive understanding of risk factors associated with work-related driving incidents. This information would provide a strong foundation for informing the review and revision of current risk controls and the development of targeted prevention activities focused on creating systemic change.

## 6. Conclusions

The findings of this study address a gap in current knowledge that has inhibited prevention activities to improve the safety of work-related drivers. Although this study identified that the scope of knowledge on risk factors associated with work-related driving incidents is reductionist, the findings present an avenue for future research to address these gaps. Designing targeted prevention activities focused on sharing the responsibility of safety across the system could be achieved through improving the capture of data. The findings of this study present the first step in development of a system thinking tool that comprehensively captures the range of factors that should be considered in the investigation of light vehicle work-related driving crashes.

## Declarations of interest

None.

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