Heavy vehicle road safety: A scan of recent literature

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Abstract

The number of registered heavy vehicles (HV) in Australia has risen by 22% since 2005 and, with the national freight task projected to double by 2030, the number of HVs on Australian roads will continue to increase. In the 12 months to the end of June 2010 crashes involving heavy vehicles resulted in 239 fatalities and around one third of all work-related road crash fatalities occur within the freight industry. Heavy vehicle safety for both the trucking industry and the general community remains an important issue. In recognition of this the Australian Trucking Association commissioned the Centre for Automotive Safety Research to undertake a research scan to develop a knowledge base that may be used to guide the strategic direction and development of effective outcomes in the area of heavy vehicle safety. The scan focussed on five key areas: factors associated with HV crashes, road and vehicle design, human and social factors, speed management and enforcement, and the effectiveness of accreditation schemes. Gaps in knowledge were identified and recommendations for future research in the areas of fatigue, seatbelt use, traffic management, and technology are suggested.

Keywords

Heavy vehicle, Truck, Safety, Crashes, Road safety, Research scan

Introduction

Heavy vehicles[1] (HV) are a common sight on Australian roads, be it rural highways or the arterial roads of major cities and towns. Statistics from the Australian Bureau of Statistics (ABS) [1] indicate that to the end of March 2010, the number of registered trucks in Australia has risen to over 536,000 since 2005, an increase of just over 22%. Furthermore, in the 12 month period ending October 2007, heavy vehicles travelled a combined total of 15,856 million kilometres with articulated trucks having the highest average kilometres driven of all vehicle types, as shown in Table 1.

Table 1. Total (in millions) and average (in thousands) kilometres travelled October 2006 to end of October 2007 [2]

	Total kms (x1,000,000)	Average kms (x1000)
Passenger vehicles	157,928	13.7
Motorcycles	1,905	3.7
Light commercial vehicles	37,385	17.1
Rigid trucks	8,644	22.0
Articulated trucks	6,929	93.2
Non-freight carrying trucks	283	14.2
Buses	2,097	31.6
All vehicles	215,171	14.6

Heavy vehicles play an integral role in the transportation of freight throughout Australia. Since 1971 the Australian road freight task has increased by a factor of 6 reaching 184,072 million tonne-kilometres in October 2007 [2], with current projections indicating that the freight task will at least double by the year 2030 [3]. It is clear that the number of heavy vehicles on Australian roads will grow in line with the increasing freight task.

Concomitant with this growth in the freight task and numbers of heavy vehicles are increases in the numbers of other vehicle types on the road network including passenger cars and motorcycles. Table 2 shows the growth in ownership of all vehicle types from 2005 to 2010 as reported in the Australian Bureau of Statistics 2010 motor vehicle survey [1]. With the growth observed across all vehicle types over the five year period it is clear that improving road safety across the entire road network will continue to be a significant issue for all road users, and particularly so for the trucking industry. Heavy vehicle safety can be considered in terms of an Occupational Health and Safety perspective or from a general road safety perspective. Both show that there is still much room for improvement.

Table 2. Growth in numbers of registered vehicles from 2005 to 2010 [1]

	2005	2010	% change
Passenger vehicles	10,896,410	12,269,305	12.6
Campervans	40,693	48,504	19.2
Light commercial vehicles	2,030,254	2,460,568	21.2
Rigid trucks	368,520	431,278	17.0
Articulated trucks	69,723	82,436	18.2
Non-freight carrying trucks	19,962	22,367	12.9
Buses	72,620	86,367	18.9
Motorcycles	421,923	660,107	56.5
Total	13,920,105	16,060,932	15.4

When considering the road freight transport industry itself, Safe Work Australia [4] report that 41 (19%) of the 295 working fatalities recorded in the 2006-07 period were in the road freight transport industry. During this same period the rate of fatal injury among road and rail drivers[2] was 25.1 per 100,000, the highest rate of fatality observed across all industries. Furthermore, road crashes are the largest cause of fatal injury in the freight industry which also accounts for one third of all work-related road crash fatalities [4]. Improving the safety of heavy vehicle operations will require ongoing attention.

When considering the road network as a whole, statistics for road crashes involving heavy vehicles provided by the Bureau of

Infrastructure, Transport, and Regional Economics [3] indicate that in the 12 month period to the end of June 2010 a total of 239 fatalities were recorded from 194 crashes involving heavy vehicles. As such, a considerable proportion of the nation's road trauma can be attributed to crashes involving heavy vehicles. While there is some evidence that HV drivers are not always at fault [5, 6] the impact of these crashes is borne by both the HV industry and the community in general. Furthermore, the advancement of HV safety (and road safety in general) requires consideration of a broad spectrum of factors of which the attribution of fault is perhaps the least important. This philosophy is consistent with best practice in the area of risk and safety management.

The purpose of the research scan is to develop an overview of current knowledge in order to guide the strategic direction and development of effective outcomes in the area of heavy vehicle safety.

Method

The research scan focussed on six key areas: understanding the factors associated with HV crashes, road design, vehicle design (incorporating interaction between HVs and other road users), human and social factors (including fatigue and licensing issues), speed management and enforcement (including general enforcement), and the effectiveness of heavy vehicle accreditation schemes.

In order to draw on the most relevant and up to date knowledge of heavy vehicle road safety an effort was made to identify peer reviewed journal papers, conference proceedings, technical papers and published reports outlining research conducted within the past decade; older publications were also included where more recent evidence was lacking. Materials were sourced from the Centre for Automotive Safety Research's extensive road safety library and a number of academic databases and industry-related indexes, including:

- **Australian Transport Index (ATRI)**. A database of Road transport resources addressing a range of subjects including: road safety, traffic accidents, heavy vehicles, freight, traffic engineering, vehicle design, road design, human factors, speed, and speed limits.
- **Transport**. A database of Transport resources covering the subjects of road safety, traffic accidents, heavy vehicles, and human factors.
- **CASR library catalogue**. A collection of over 25,000 items relevant to the study of road safety, vehicle safety, vehicle design, human factors, speed, and licensing.
- **Academic Search Premier**. A Multi-disciplinary database.
- PsycInfo. A database of the American Psychological Association (APA) covering subjects relevant to behavioural science and human factors.
- **Informit**. A Wide range of databases covering subjects including health, business, humanities, social sciences.
- **Compendex**. A Scientific and technical research database. Subjects: engineering.

Internet search engines such as Google and Google Scholar were also utilised to identify publicly available resources on the internet. The websites of key Australian and international trucking and road safety organisations were also searched for publicly available materials relevant to the aims of the research scan.

A research scan differs to a literature review in that where a review offers critical analysis of evidence a *research scan,* on the other hand, seeks only to identify the extent of existing research and the state of current knowledge based on that body of evidence. As such, the present scan provides a summary of findings only, and offers no critical evaluation of the findings presented.

In total 280 publications were identified and included in the research scan; a summary of this work is provided herein. Given the considerable scope of the project and the time constraints governing its completion it is possible that additional, relevant materials may not have been included.

Discussion

The goal of the present research scan was to consolidate existing knowledge with regard to various factors associated with the safety of HVs. Much of this research is concerned with the safety of articulated HVs (e.g., B-doubles) although there is a small body of literature regarding rigid HVs. A brief overview of research findings relating to heavy vehicle crashes, road and vehicle design, human and social factors, speed management and enforcement, and accreditation schemes is provided below. Throughout the research scan a number of knowledge gaps were identified as potential targets for future investigation. In recognition of the impracticalities of undertaking such an extensive research program a number of areas were identified as offering the most benefit to HV road safety. Recommendations for a suggested program of research are made.

Heavy vehicle crash factors

An investigation of factors associated with HV crashes focussed on research providing evidence of causal factors or the identification of factors that contribute to the death or injury of people involved. There is an extensive body of literature examining the characteristics of HV crashes providing a wealth of information with regard to the role of speed, driver factors (such as fatigue, substance use, and general medical condition), seatbelt use, infrastructure issues (e.g., road design, condition, and alignment), vehicle factors (e.g., mechanical condition, type, load, and configuration), and issues associated with vehicle control.

Evidence from Australian and international sources indicates that single vehicle crashes, particularly loss of control type crashes, account for the majority of HV crashes [7, 8]. Further evidence indicated that the majority of fatal HV crashes occur on rural highways during daylight hours and under favourable weather conditions [9, 10]. According to recent statistics published by National Transport Insurance's National Truck Accident Research Centre [7], 37% of HV crashes occur on designated highways, and the majority of crashes occur when road use is heaviest, with the 11.00am to 2.00pm period being the worst. The causal factors most commonly associated with HV crashes include excessive or inappropriate speed and fatigue [8, 11-13], while the mechanical condition (particularly brakes) and load characteristics of the vehicle are also associated with HV crashes [9, 12]. Statistics published by National Transport Insurance (NTI) [7] also indicate that 32% of HV crashes involve inappropriate speed and 10% fatigue; 42% of crashes involve both fatigue and inappropriate speed.

Road design

An examination of road characteristics relevant to HV safety focussed on evidence related to road infrastructure (e.g., engineering treatments, line markings, and clear zones), road features (e.g., intersections, road alignment, and road condition), and traffic management (e.g., signage and route access).

A number of road design features presenting safety issues for HV drivers were identified. Evidence indicated that road design and infrastructure could be improved to better accommodate HVs, particularly along recognised freight routes in both rural and urban areas. Treatments such as shoulder sealing have been found to provide a simple, cost-effective means for improving safety for all road users [14], while other evidence indicated that the use of truck climbing lanes and lane restrictions for HVs offered safety benefits without major disruptions to traffic flow [15-17]. Aspects of the urban freight route environment that have been identified included signal phase timing, particularly from amber to red, lane width and storage lengths, and kerb radii for turns [18, 19]. Evidence also indicated that the provision of rest areas throughout Australia is inadequate and does not align with established guidelines with regard to both the facilities provided and the frequency of rest stops along individual routes [20].

Vehicle design

The design of HVs is also an important consideration with regard to HV safety for both HV drivers and other road users. A scan of HV design literature focussed on areas related to vehicle features such as underrun protection and safety technologies, and factors associated with HV interactions with other road users.

Following the discussion of road design above, the risks associated with road design features can also be ameliorated through vehicle design and technologies. On-board warning systems can be used in conjunction with Intelligent Transport Systems (ITS) to forewarn drivers of potential hazards allowing them to take proactive steps to reduce those risks [21]. For example, warning drivers that their speed may be inappropriate for an upcoming bend will enable them to slow to a more appropriate speed before entering the curve. Intelligent Speed Adaptation (ISA) technologies can further reduce HV risks associated with speed, while other technologies such as Electronic Stability Control (ESC), Vehicle Stability Systems (VSS), Yaw Stability Control (YSC), and Electronically controlled Braking Systems (EBS) that improve the stability and control of the vehicle under normal or emergency driving conditions also have the potential to improve HV safety [22-26]. Digital short-range communications (DSRC) also hold significant potential for improving the operational safety of all vehicles on the road network [27]. At present the development of new crash avoidance technologies proceeds apace however, until evaluations of these technologies are conducted it is difficult to state with any certainty their benefits for road and HV safety. It should be noted that many of the technologies identified herein are still in their infancy, as such the safety benefits offered by these has yet to be fully examined (see recommendations for future research below).

The advent of on-board technologies will provide new sources of data that can be used in infrastructure design and management, and may also provide other avenues for enforcement and improving compliance.

The design of HVs has also been found to influence the involvement in, and outcomes of, an HV crash. The aggressivity[3] of HVs plays a key role in the injuries of the occupants of other vehicles and vulnerable road users (i.e., cyclists, pedestrians, and motorcyclists) [30], while the generally poor crashworthiness[4] of trucks has been identified as a significant issue where cabin integrity is compromised during roll over or collision with a fixed object [31].

Human and social factors

There is an extensive body of research pertaining to a variety of human and social factors associated with driving-related and other aspects of human performance. While all of this research is of relevance to the HV industry, a sub-set of HV specific research is also available. A scan of this research focussed on the safety issues surrounding health (including mental health), fatigue and sleep, substance use, and behaviour.

Investigations of HV driver health have revealed that a number of adverse health outcomes are associated with HV driving including obesity, cardiovascular disease, diabetes, and sleep apnoea [32-34]. A limited number of studies have examined the extent of mental health issues for HV drivers, those that have been conducted suggest that the prevalence of mental health issues such as anxiety and depression are in line with those observed amongst the Australian population [35, 36]. This research has also linked mental health issues with an increased risk of crashing and that HV drivers face a number of barriers to obtaining treatment for these issues [36].

Fatigue and sleep-related issues are also an issue of significant concern within the HV industry and have been identified as a risk factor for HV crashes. A general body of research has identified that fatigue has a detrimental effect on performance in terms of attention and reaction times, vehicle control, and deterioration in general performance (for a comprehensive review see [37]). Other research has indicated that HV drivers may have a higher risk of fatigue-related crashes compared to other road users due to the nature of their work (e.g., shift work, long hours, monotonous activity) and their lifestyle (increased risk of sleep disorders due to medical conditions such as obesity) [38-40]. Sleep apnoea has also been linked with impairments in driving performance and is a significant issue within the HV industry as a confluence of lifestyle factors (e.g., sedentary lifestyle and poor diet) increase the likelihood of sleep apnoea among HV drivers [41].

Another human factor that presents a significant issue for road safety is the use of licit and illicit substances. Investigations of substance use among HV drivers have indicated that the prevalence of substance use among this group is comparable to that of the broader Australian population [42]. Evidence also indicated that the most commonly used substances by HV drivers were stimulants (e.g., amphetamines and methamphetamines, pseudoephedrine, and cocaine), which appeared to be predominantly used as a fatigue countermeasure [42, 43]. Given the high prevalence of medical conditions among HV drivers an effort was made to identify literature regarding the effects of prescription medications on HV driver safety. No such research was identified.

Any consideration of human factors must also examine driver behaviours. One of the key issues identified within the present literature is the low prevalence of seatbelt use among HV occupants [44, 45]. Evidence suggested that HV drivers have a number of misconceptions with regard to the comfort and safety benefits of seatbelts that contribute to this lower prevalence [44, 46]. Safety consciousness and enforcement consequences were factors commonly reported by drivers as reasons for always using a seatbelt [44, 47, 48]. The effects of driver training were also examined. Evidence indicated that training in a number of areas (e.g., numeracy and literacy, and safety management) can improve safety of HV drivers [49, 50]. While no evaluations of current driver training practices were identified the evidence questioning the effectiveness of these practices was identified [51].

Speed management and enforcement

Speed and the management of speeding vehicles is one of the most important issues in road safety [52, 53]. As such, research regarding the management of speed and the general enforcement practices of police and other regulatory authorities were also examined as part of the current research scan.

Evidence identified by the scan indicated that speed is an issue for heavy vehicle safety. Inappropriate speed (i.e., driving too fast for the conditions) or driving over the posted speed limit was found to be one of the major contributing factors to HV crashes [8, 11-13]. Evidence also indicated that, due to the proportions involved, low level speeding is a significant safety concern for HVs. There was also some indication that on-board technologies such as speed limiters and ISA can provide safety benefits with regard to the management of HV speed [23].

There was a lack of literature regarding HV-specific enforcement practices however, much of the general traffic enforcement literature was still relevant to HV operations. The majority of this literature discussed the effectiveness of police operations targeting speeding behaviour. This evidence revealed that police enforcement campaigns play an important role in affecting the behaviour of all road users with a variety of strategies found to produce a number of safety benefits. For example, high visibility operations effectively reduced speeds on targeted roads and, to a lesser extent, surrounding roads, although this effect is relatively short lived following the cessation of police operations [54, 55]. Research has also demonstrated that speed cameras also effectively lower average speeds and reduce crashes on roads where they are installed [56]. The use of mobile radars has been found to produce similar effects [57].

As discussed previously the advent of telematics and digital short-range communications (e.g., vehicle-to-vehicle and vehicle-to-infrastructure) has the potential to improve the management of the complex task of HV compliance, creating a more efficient and effective system of enforcement. However, it will be important to resolve a number of issues regarding the use of new technologies, including how these technologies will be used by enforcement agencies and ensuring the reliability and accuracy of both stored and collected data.

Accreditation schemes

Safety accreditation schemes provide an alternative means for ensuring heavy vehicle operator compliance with recognised safe operating standards. These standards address a range of issues including fitness to drive and driver health, training, vehicle maintenance, and the management of transport operations.

Three studies were found that evaluated accreditation schemes. Safety benefits of accreditation within the HV industry was determined by comparing the crash rates of vehicles from accredited operations to those from non-accredited operations. These studies have demonstrated the positive safety benefits to be derived from accreditation. For example, vehicles from accredited HV operations had 50-75% fewer crashes than vehicles from non-accredited operations [58]. Similarly, compliance reviews undertaken as part of the accreditation process reduced HV crashes by up to 40% with this reduction in crashes remaining stable for a minimum of seven years following the review [59].

Recommendations for future research

The consolidation of evidence achieved in the research scan brought to light a number of gaps in the current state of knowledge[5]. While further research is required to fill each of these gaps the following recommendations are offered as a point of departure.

1. Fatigue was identified as a clear issue for the heavy vehicle industry. Given the current state of knowledge it is

recommended that future research seek to improve the management of fatigue within the HV industry. One such line of inquiry should seek to identify HV drivers who may have an increased risk of fatigue related crashes.

2. Indications of restraint use among HV drivers suggested that compliance with seatbelt use is low with estimates ranging from 4-30% [44, 60]. Estimates indicate that the benefits of increasing seatbelt use among HV drivers would effectively prevent 37% of fatalities, 36% of serious injuries, and 22% of slightly injured truck occupants [61]. Research to improve seatbelt use among heavy vehicle occupants should seek to identify the characteristics of HV occupants and other factors related to restraint use that may be amenable to change.
3. International research indicated that lane and speed restrictions for HVs on some road sections have positive effects for road safety in these areas. Research should evaluate the effectiveness of such strategies under Australian conditions. This research could also investigate the effect of these restrictions on traffic flow and productivity of the HV industry.
4. Numerous technologies with potential safety benefits for HVs were identified. Evaluations of the effectiveness of these technologies will assist the HV industry in the identification of those technologies that offer the greatest benefits for HV safety. Such research is important given the rate at which existing technologies evolve and new technologies are developed. It is also important to identify ways in which the most at risk HV drivers benefit most from these technologies.

Closing comments

It should be noted that the leading road safety countries are now transitioning to a systems approach to road safety. This is based on an acknowledgement that humans are fallible and, therefore, the design of transportation systems, including the roads on which people travel, the vehicles in which people travel, and the speeds at which people travel need to accommodate human errors in order to reduce severity of injury outcomes. The approach adopted in Australia is the Safe Systems approach and is becoming an integral part of road safety strategy and action plans over the next decade. Efforts to improve heavy vehicle safety will be considered by road authorities in this context over the next decade. Additionally, the transition to a national heavy vehicle regulator is currently underway and this will provide a further change in context to the way in which heavy vehicle safety will be considered into the future.

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The complete research scan *Heavy vehicle safety: Research scan* is available from http://casr.adelaide.edu.au/publications/

Notes

[1]The term Heavy Vehicle (HV) refers to rigid and articulated vehicles with a gross vehicle mass (GVM) of 8 tonnes or greater.

[2] The statistics provided in this paper are, as closely as possible, tailored to the road freight (i.e., HV) industry however, due to the manner in which Safework Australia statistics are collated there may be some crossover with other aspects of the Transportation and Storage industries (e.g., occupations associated with rail and freight management).

[3]Aggressivity refers to the degree of protection a vehicle provides for other vehicles and road users with which it collides (28. Newstead S, Watson L, Cameron M. Vehicle safety ratings estimated from police reported crash data: 2009 update. Melbourne: Monash University Accident Research Centre2009. Report No.: 287. In general terms vehicles of higher mass fare better than vehicles of lower mass in a collision (29. Evans L, Frick MC. Mass ratio and relative driver fatality risk in two-vehicle crashes. Accident Analysis & Prevention. 1993;25(2):213-24.

[4]Crashworthiness refers to the protection a vehicle affords its occupants in the advent of a crash. This incorporates factors such as the integrity of the passenger space and secondary restraint features such as airbags and seatbelts (28. Newstead S, Watson L, Cameron M. Vehicle safety ratings estimated from police reported crash data: 2009 update. Melbourne: Monash University Accident Research Centre2009. Report No.: 287.

[5]An extensive list of research gaps and areas for future research are provided in the full report.

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Investigating the role of fatigue, sleep and sleep disorders in commercial vehicle crashes: A systematic review

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Abstract

Commercial vehicle driving is an occupation in which increasing demands are being placed on drivers as a consequence of economic and trade expansion. Crash rates are high, as is the injury risk to all road users where commercial vehicles are involved. Fatigue and sleep deprivation are of increasing concern, and sleep disorders have been shown in car drivers to increase crash risk. Commercial drivers may have higher crash risk due to exposure and high sleep disorder prevalence; however, reviews thus far have not provided sufficient conclusion. The aim of this systematic review was to investigate the evidence of the role of fatigue, sleep and sleep disorders in commercial motor vehicle crashes. Relevant electronic databases and grey literature were searched and 16 peer-reviewed published studies met the study criteria. Factors found to have an association with crashes were daytime sleepiness (Epworth Sleepiness Scale), and sleep debt. While not employed as a search term, obesity was shown to be a risk factor for sleep disorders, daytime sleepiness and incurring a crash or near miss. Most studies suffered from small sample size as well as specific methodological flaws making generalisation difficult and indicating the need for a large, well-designed study with empirical measures of both risk factors and outcomes.

Keywords

Sleep disorder, Commercial driver, Sleepiness, Crash

Introduction

The commercial motor vehicle (CMV) driver faces a challenging work environment. With increasing demands on the heavy vehicle industry, alongside economic and trade expansion, safety concerns are paramount. Crash rates are high [1], as is the injury risk to all road users [2] where heavy vehicles are involved. While fatigue and sleep deprivation have been recognised as factors critical to the safety and performance of commercial motor vehicle drivers [3,4], there is inconclusive evidence for the interplay and strength of associations of other sleep-related risk factors for CMV crashes including sleep disorders such as sleep apnoea and excessive daytime sleepiness, alongside associated factors such as the drivers' health status.

Systematic reviews to date have included some studies of CMV populations; however, there is no current review investigating the crash risk associated with fatigue, sleep or sleep disorders solely among CMV drivers. Connor et al [5] investigated the role of driver sleepiness across studies of car drivers and highlighted a positive association, albeit based on a paucity of