

Summary of an evidence-based safety management system for heavy vehicle transport operations

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Background to this Study

Heavy vehicle crashes involving serious injuries and deaths are still occurring in large numbers in Australia and in many other countries. These serious injuries and deaths are preventable. However, while much is known about the causes of heavy vehicle related deaths and injuries, there is little knowledge about what kinds and combinations of management practices can best reduce the risk of these deaths and injuries.

At a regulatory level, governments have made efforts to reduce risk factors such as driver fatigue and unsafe driving speeds through legislation and enforcement of driver working hours and permissible speed limits. Moreover, there is a growing recognition of influences on truck drivers from within their companies and the industry more generally. The 'chain of responsibility' principle has now been adopted in Australian transport regulations, in addition to occupational health and safety regulations. Some governments have also encouraged the uptake of 'alternative compliance' schemes by allowing accreditation to the Australian Trucking Association's TruckSafe program and/or adoption of the Australian Logistic Council's National Logistics Safety Code, to be used as a 'reasonable steps' defence in occupational injury prosecution cases. However, these schemes have not yet been independently evaluated.

Until this study, much of road safety research had been founded on the epidemiological principles embodied in the two-dimensional Haddon Matrix (Haddon, 1968). This method of analysis has led to the development of many effective road safety interventions at a macro-societal level, such as random breath testing, road safety audits, and new car assessment programs. Those researching work related road safety have tried to adapt the Haddon Matrix, particularly in broadening the definition of "environmental factors" to include organisational factors (Murray et al., 2009; Runyan, 1998). However, it has been argued that this approach will always have limited value as it does not enable a dynamic systems analysis (Mooren et al., 2009; Salmon and Lenné, 2015). Using a systems approach, road injury risk factors could be understood as *management system* deficits that require a complex system strengthening response involving policy development and enforcement, work and journey planning, safety risk management education and other systematic management actions. The management system is characterised by a fluid interaction among managers, drivers and others within an organisation, as well as these interactions being influenced by external environmental systems (Stuckey et al., 2007). A paradigm shift in road safety thinking is needed and a systems approach provides that opportunity to think about solutions in a different way from the traditional method of applying a static epidemiological analysis of injury contribution factors.

Aims of the Study

This research set out to develop an evidence-based safety management system suitable for heavy vehicle transport operations, by identifying the practices that distinguish companies that have poorer safety records and those that have better safety records. Truck damage insurance claim rates were used as a proxy measure of safety outcomes and to distinguish poorer and better performing companies. Companies with lower insurance claim rates were judged to have better safety records than companies with higher claim rates.

The overall aim of the research was to develop a set of characteristics and practices relating to safety management that, if implemented, would be likely to produce better safety outcomes. Two specific objectives of this research were to:

1. identify the distinguishing characteristics and practices of heavy vehicle transport operating companies with good safety records and those with poorer safety records; and
2. develop an evidence-based safety management system suitable for companies that operate heavy vehicles for transport of goods that will achieve good safety outcomes.

Methods

This study has taken a systematic approach to gathering evidence about the practices of truck operators that distinguish companies with good safety results (lower crash outcomes) from those with poorer safety results. Instead of starting with injury factors identified from past crashes, the emphasis of this study was to identify management and organisational practices associated with good and less good safety outcomes. In other words, it examined comparatively approaches to managing injury risk rather than dissecting the risk itself and trying out ways of reducing the risk. The starting point was differing levels of risk environments and the discovery of differing features of risk management systems. The research was designed as three consecutive studies, each building on knowledge gained from the study carried out before.

Study 1 was a systematic scientific literature review that aimed to identify effective safety management practices and organisational characteristics associated with good safety performance in any industry sector. The aim was to find existing safety management practices that have shown evidence-based statistically significant associations with safety related outcomes. The Study produced a list of practices that might be expected to have links to positive safety outcomes (lower crash and injury rates) when applied to the heavy vehicle transport sector. The results from this Study were used to inform the choice of items to be tested in a survey of heavy vehicle transport operating companies (Study 2).

Study 2 was a survey of companies operating heavy trucks to compare practices of those companies that have lower (truck) insurance claim rates with those with higher (truck) insurance claim rates. Insurance claim rates were used as a proxy representation of crash outcomes. The objective of this survey was to identify organisational and management characteristics that differentiated between companies with better and less good safety performance in terms of these measures.

Study 3 was an in-depth qualitative investigation designed to validate the findings of the Study 2 survey. This research attempted to confirm or refute practices found in the previous study to distinguish between companies with lower and higher insurance claim rates identified in the survey. The collection of data involved interviews with managers who participated in the previous survey, collection or sighting of documents relevant to the practices of interest, making visual observations and interviewing drivers to find evidence of those distinguishing practices.

In this précis, the analysis of all data collected in Studies 1, 2 and 3 is used to develop a safety management system that is suitable for implementing in companies that operate heavy trucks that should reduce crash outcomes. This research is important because there has been no previous attempt to develop an SMS for this industry. Furthermore, there have been few attempts to develop an evidence-based SMS with a validated set of safety management characteristics for any industry.

Summary of Study 1, 2 and 3 findings

Strategic literature review (Study 1) findings

Knowledge gained from the scientific literature identified a number of specific safety management interventions associated with good safety performance. In order of most to least number of relevant studies found, the safety practices shown to have significant links with safety outcomes included: management commitment/safety climate (30 studies), worker input to WHS, safety communications (21 studies), vehicle/workplace conditions (13 studies), safety training (12 studies), scheduling/journey planning/work pressure (11 studies), safety management systems/accreditation schemes (9 studies), safety policies/procedures/enforcement (8 studies), financial performance/pay systems/pay rates/unionisation (8 studies), risk analysis and corrective actions (8 studies), incentives (7 studies), size of organisation/truck fleet/freight type (6 studies), worker characteristics/driver attitudes/behaviours/health (4), hiring practices/driver retention/return to work policies (4), and prior safety violations, crashes/incidents (2).

This wide range of characteristics was found from studies using limited research methodology. Most of the studies were cross-sectional surveys that did not provide a clear case for the direction of influence of the characteristics studied. It was therefore necessary to design a study to investigate associations between safety outcomes and safety management characteristics.

Survey of managers (Study 2) findings

The design of Study 2, a survey of managers, was to administer a questionnaire to those in companies with lower and higher insurance claim rates. All of the Study 1 characteristics, except for management commitment/safety climate and financial performance, were included in the survey questionnaire. Management commitment/safety climate could not be accurately tested by asking managers about these characteristics as social desirability in survey responses would render the findings questionable (Grimm, 2010). Management commitment and safety climate are characteristics that are seen when there is a sufficient accumulation of a range of good practices (DeJoy et al., 2010; Williamson et al., 1997). Therefore, the survey, focused on tangible verifiable safety management characteristics, was expected to shed some light on management commitment to safety when investigated in Study 3. Also, questions on profitability of companies were excluded due to likely sensitivities about companies revealing their financial position.

This survey identified 37 characteristics found to distinguish between lower and higher truck insurance claiming companies. Seventeen of the characteristics were expected, based on the Study 1 findings from the scientific safety management literature. The findings on 20 of the characteristics were not expected, based on the fact that the findings were not consistent with what good safety might be expected to look like. For example, the Study 2 survey found higher claimers had more policies, did more training of drivers and did more driver-monitoring, all of which have been found to be associated with safety in previous research.

Due to the limitations of self-report surveys, as well as a number of unexpected findings, it was important to carry out a further study to validate the survey findings. This is also a unique characteristic of the research design used in this study.

In-depth investigation validation of survey (Study 3) findings

Study 3 was designed to investigate the validity of Study 2 survey findings through an in-depth audit of these findings involving interviews of a sample of managers who participated in the original survey, a survey/interview of drivers, on-site observations and documentary review. Figure 1 shows a summary of the findings from the Study 3 in-depth investigation of the 37 characteristics that distinguished lower and higher claimers in the Study 2 survey. As shown in the figure, the Study 3 in-depth investigation was able to validate 27 characteristics (73%) of the 37 that were found in Study 2 to differentiate between lower and higher claimers with respect to safety management. These included 16 characteristics that, based on the scientific safety literature, were expected - that is, characteristics that are thought to improve safety management, and were more prevalent in companies with lower insurance claim rates. These 16 characteristics represent specific ways in which lower-claiming companies managed safety risks associated with the work environment, the drivers and communications. These are presented in Table 1. The study also validated eleven distinguishing characteristics that were unexpected or inconsistent with what might be expected based on previous research on safety management, including higher claimers having more policies, accreditations, doing more training, and monitoring than lower claimers. These were policies and practices that have been thought to represent good safety management, and yet higher claimers were found in this study to be more likely to have them in place. These results call into question the value of these policies and practices for safety management.

Four of the 37 characteristics were found in the investigation not to be validated. All of these were characteristics not expected of poorer safety performers on the basis of prior research. In the case of driver recruitment checks and safety KPIs, managers in higher-claiming companies admitted that they do not have these practices in place. With regard to safety training, the drivers in higher-claiming companies reported that these programs were not offered by their companies. Therefore, it was concluded that higher claimers were not more likely than lower claimers to have them. These findings mean that these characteristics cannot be included in the safety management system presented in this paper.

For six characteristics there were insufficient data from the in-depth study to make a conclusion about their validity, and therefore they were deemed to be inconclusive. Of the six characteristics neither validated, nor invalidated, five were findings from Study 2 that were not expected based on prior

research. The validation of one expected finding - that lower claimers were more likely than higher claimers to schedule and roster drivers from a central base - could neither be confirmed, nor refuted. The only expected finding that could not be validated was central versus local scheduling and rostering. The testing of this variable seemed to be confounded by smaller companies where drivers in the companies with only one site said that this was a central and a local practice. Two of the five unexpected findings concerning actions taken when drivers breached working hours were somewhat confounded by a number of lower-claiming companies that indicated only that the problem does not arise, and hence did not have practices in place to deal with it. The other three unexpected findings were not sufficiently tested in Study 3 to make conclusions about them. The lack of evidence to support these characteristics does not mean that they are refuted. Additional research could be applied to further test these characteristics. However, these characteristics cannot be included in the evidence-based safety management system (SMS).

The in-depth investigation also revealed an additional characteristic relating to the style or culture of the company, which again differentiated lower- from higher-claiming companies. This characteristic was that managers in lower claimers, as distinct from higher claimers, demonstrated acceptance of responsibility, leadership and proactive approaches to safety management. Study 3 found strong evidence that managers in lower-claiming companies, but not higher-claiming companies, were more vigilant and proactive in their efforts to ensure they were doing all that was possible to assure safe transport operations. Higher claimers, by contrast, often made comments to the effect that they place safety management responsibilities solely on the drivers. This additional characteristic was therefore included in the final evidence-based SMS.

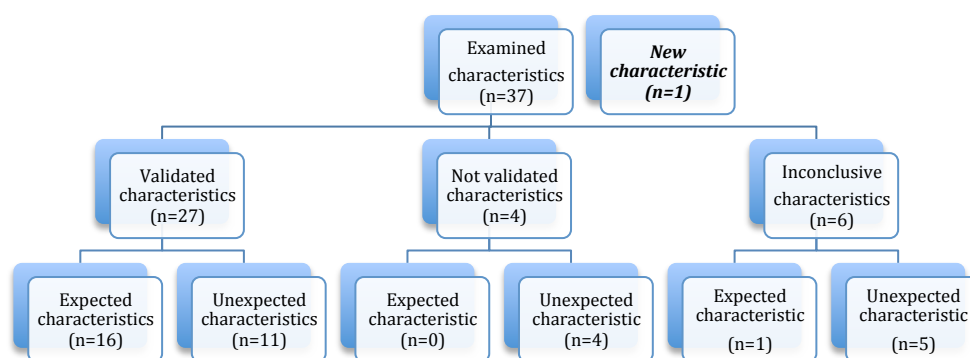


Figure 1 Summary validation findings from Study 3

At the end of the survey and validation process, a set of 17 characteristics was revealed: 16 validated characteristics and one arising from the validation process itself, all of which had been shown to distinguish lower- from higher-claiming companies, and where good practices were more likely to be found in lower-claiming companies. These characteristics formed the basis of an evidence-based SMS that will be discussed in more detail in the next section.

Set of evidence-based safety management characteristics

The culmination of the three studies provided a set of characteristics of trucking companies that are at least associated with lower claims for safety related incidents. These characteristics form the basis for the development of an evidence-based safety management system. This set of 17 characteristics are most likely not an exhaustive set of elements or characteristics/practices of an SMS. There may well be others, but this set distinguished lower- and higher- claiming trucking companies. Unlike many other studies of the potential components of safety management systems, the elements of this SMS were validated by triangulating the results of three research studies.

The characteristics were then reframed as implementable safety management *practices* and grouped into logical management items. This involved combining two characteristics relating to driver

remuneration into one. That is, the characteristics “pay by time worked” and “pay to wait” were combined as “drivers are paid for all hours worked regardless of task or activity”. Also, “pre-trip inspection checks” were linked to having “fewer defect notices” for practical purposes, forming a single practice, “maintenance and pre-trip vehicle checks ensure that trucks are in safe conditions for all trips”. This resulted in a total of 14 auditable SMS management practices, as shown in Table 1. The 14 practices were then grouped into topic areas and the topic areas further grouped under headings:

- *Risk assessment and management (6 practices)* – covering topics relating to fleet, environment and job risk safety management;
- *Driver risk management (6 practices)* – covering driver employment, remuneration, training, monitoring, discipline and incentives; and
- *Safety culture management (2 practices)* – covering communication management.

Table 1 Evidence-based safety management characteristics and practices

Group	Topic	Study finding – validated characteristics	Evidence-based management practices
Risk assessment and management	Fleet	Safety features in choosing vehicles	All appropriate safety equipment, including safety features on trucks, is provided
		Fewer defect notices	Maintenance and pre-trip vehicle checks ensure that trucks are in a safe condition for all trips
		Pre-trip inspection checks	
	Journey risk assessment	Check traffic conditions	Route risk assessments are done for all delivery journeys
		Speed limiting on poorer quality roads	
	Site risk assessment	Safety audits at own sites	Site and job risk assessments are regularly carried out
Driver risk management	Monitoring	Document fatigue management	Monitor fatigue management practices
	Response to safety concerns	Time limits on response to drivers’ safety concerns	All managers respond quickly to safety concerns raised by drivers
	Recruitment/employment	Check accident history	Recruitment criteria focus on safe driving records
		Fewer drivers over 60	Driver fitness is assessed to ensure drivers’ abilities to safely carry out all job duties
	Pay/conditions	Pay by time worked (not by trip or load)	Drivers are paid for all hours worked regardless of the task or activity
		Pay to wait	
	Training	Experienced drivers check/coach other drivers	Training for drivers is based on individual tuition by experienced safe drivers
Safety culture	Discipline	Formal investigation of unsafe behaviour	Identified unsafe behaviours are formally investigated
	Incentives	Offer incentives for safety innovations	Drivers are given incentives, including monetary incentives, clearly linked to work safety efforts
	Communication	Encourage driver input into WHS	Managers encourage driver input to WHS decision-making
		Show management commitment to safety management	Managers take responsibility and show leadership in making safety a clear priority

These evidence-based practices were used to construct a safety management system. The fourteen management practices are more fully described, together with the rationale for including them in the SMS in the next three sections.

In providing the rationale for these safety management practices, evidence from the original research conducted in Studies 2 and 3 forms the foundation of the rationale for their inclusion. Supplementary evidence from previous empirical research, documented in the scientific safety literature, is incorporated to provide further context to strengthen the rationale for including each practice and to provide suggested methods for measurement.

Evidence-based safety risk assessment and management practices (6)

For the first grouping, *risk assessment and management*, there are six evidence-based practices. These safety management elements focus on assessing and managing risks associated with freight, trucks, sites, journeys and improving safety of the workplace and work system by analysing and remediating risks. These are described and justified below.

1) All appropriate safety equipment, including safety features on trucks, is provided

The set of three studies found converging evidence to support the conclusion that a safety management system (SMS) should include the practice, that ***all appropriate safety equipment, including safety features on trucks, is provided***.

A myriad of optional safety features can be purchased with new trucks, including electronic stability control, speed and lane assist devices, underrun protection, integrated seatbelt and suspension seat, anti-lock braking systems, tyre pressure monitoring systems, non-slip steps and GPS. Prior research has found that these features can either assist the driver to avoid crashes/accidents or minimise the harm in the event of a crash/accident, and should be considered for inclusion when truck purchases are made (Langwieder et al., 2001; Mahmood et al., 2006; Muresan, 2007). The Study 2 finding that managers in lower-claiming companies were more likely than those in higher-claiming companies to consider at least one safety feature was validated in Study 3. The current research also provided ideas on how to achieve this safety management practice. Managers in lower-claiming companies explained how they take into consideration the freight carried and the needs of each individual driver when purchasing and equipping each truck in their fleets.

Ensuring that all appropriate safety equipment is provided is a practice that can improve safety and can be readily audited. It is also possible to audit a company's truck fleet to assess whether or not the company has implemented this item.

2) Maintenance and pre-trip checks ensure that trucks are in a safe condition for all trips

The research also found converging evidence to support the conclusion that the practice of ***maintenance and pre-trip checks ensure that trucks are in a safe condition for all trips***, is an important component for inclusion in the SMS.

Prior research has found that good safety management dictates that, before each driving journey, the condition of the truck and its equipment and load be checked for soundness and incident prevention (Cantor et al., 2010; Friswell and Williamson, 2010), and maintenance be regularly attended to. Participating companies in the current research provided suggestions for ensuring vehicle maintenance is a priority. Study 3 found that while managers in both lower and higher-claiming companies appreciated the need to maintain the trucks in good working order, the lower claimers were more inclusive of driver input and gave more individual attention to each truck and driver combination.

Ensuring that trucks are in a safe condition for every delivery journey could involve the practice of managers and drivers doing pre-trip vehicle checks, and keeping maintenance records on each individual truck. Again, it is possible to audit a company's truck fleet to assess whether or not the company has implemented this item.

3) Route risk assessments are completed when planning all delivery journeys

The results of the three studies indicate that **route risk assessments are completed when planning all delivery journeys** is likely to improve safety. Study 3 confirmed that lower claimers were more likely than higher claimers to check traffic conditions and limit speeds on poorer quality roads. In a study of light/short haul truck drivers, a common concern of these drivers were the potential hazards that they may encounter on the roads they travel (Friswell and Williamson, 2010), suggesting the importance of route risk assessment. A route risk assessment can involve checking road, bridge, traffic and weather conditions as well as other possible hazards such as animals on the road or road works.

Rest areas and parking areas should be identified and plans for stopping to rest should be included in the trip plan (Sabbagh-Ehrlich et al., 2005). Contingency planning may involve identification of alternative routes, and stopping areas, and making provisions for drivers to contact the manager in the event of any hazard or delay encountered. In this research, one lower claimer advised that, whenever a task involved a driver travelling to an area not within satellite phone contact, an additional driver would be sent in the vehicle. There are now quite sophisticated tools for assessing truck route risks (Cassini, 1998; Chen and Chen, 2011). An assessment of the risks that the driver may encounter en route should be made and a trip plan prepared, highlighting the risks that will need to be managed by the driver and the manager. These trip plans can be documented and audited.

4) Site and job risk assessments are regularly carried out

Prior research discussed in Chapter 3, together with the original survey and its validation, support the inclusion in an SMS of the practice, **site and job risk assessments are regularly carried out**. Both the physical and psychosocial work environments can influence safety and injury outcomes (Bjerkan, 2010; Cui et al., 2013; Geldart et al., 2010). It follows that in the road freight transport industry, drivers should be alerted to any potential hazards on any site visited. Job risk assessments should also identify any safety risks associated with particular tasks that may be performed by the driver (Wachter and Yorio, 2014). Site risk assessments or job safety analysis procedures were more prevalent in companies with lower insurance claims and they provide ideas for encouraging and managing regular risk assessments. One lower claimer provided a monetary incentive for completing risk assessments each week. Another lower claimer showed documents outlining specific risk assessment procedures for every customer site. Some of the managers in lower-claiming companies provided copies of job and site risk assessment forms. These forms and procedures are readily implementable and auditable.

5) Monitor fatigue management practices

The combination of findings from prior research and Studies 2 and 3 regarding the links between worker/driver fitness and safety performance provides evidence to support inclusion of **monitor fatigue management practices** in the safety management system.

Fatigue is a major driving risk for truck drivers. The testing of driver performance fitness on a simulator¹ in New Zealand found that 9% of drivers did not meet the pre-defined driver fitness performance criteria (Baas et al., 2000). The implications suggest that driver fitness checks, in some form, are warranted.

Moreover, safe journey plans are required by a determination of the, now disbanded, Australian Road Safety Remuneration Tribunal. Delivery times may be extended due to a variety of factors that may cause travel delays. It is important, whether or not there is a delay or hours extended, that a driver must be urged to stop and rest when tired. While the recording of working and rest hours are required of every driver by law, the manager under Chain of Responsibility provisions is also responsible for ensuring that drivers are fit for duty and do not exceed safe working hours, regardless of regulatory limits on hours of work.

Study 3 found that while lower claimers were vigilant in checking driver fitness prior to delivery journeys, higher claimers were not vigilant. Fatigue and fitness for duty are documented and are always checked

¹ Criteria validated in California. See Stein, A. C., Parseghian, Z., Allen, R. W., Miller, J. C. 1992). High risk driver project: Theory, development and validation of the Truck Operator Proficiency System TOPS) Vol. 2: Report. Hawthorne, CA: Systems Technology, Inc. Technical Report 2417-1).

by managers in lower-claiming companies, but not always by those in higher-claiming companies. The pre-trip checks include ensuring that both driver and vehicle are fit for the tasks assigned each day. Higher claimers left the responsibility for risk assessment largely to the drivers. For example, a manager in a higher-claiming company said that working out breaks during the journey is up to the driver, whereas a manager in a lower-claiming company advised that he sits down with each driver and together they plan the tasks.

The Study 2 survey did not detect differences between lower and higher claimers in checking driver fitness through medical or other tests. However, in Study 3 it was discovered through managers' interviews and policy documents that drug and/or alcohol testing is more prevalent in lower-claiming companies (50%) compared with higher-claiming companies (25%). In addition, one lower claimer visually assesses drivers each day and, if drugs or alcohol are suspected, the driver is not permitted to drive that day. Also, another lower claimer advised that he was considering the introduction of alcohol ignition interlocks on trucks. A manager in one of the higher claimers reported that the company conducts tests drivers for cannabis on recruitment but that he personally did not think this was fair, indicating that many drivers did not come back for interview after their tests (as so many drivers are cannabis users). By contrast, two of the lower claimers conduct random tests of drivers.

Signed forms indicating fitness for duty as well as results of random drug and alcohol testing can be kept on record for auditing purposes.

6) All managers respond quickly to safety concerns raised by drivers

Study 3 validated the Study 2 finding that managers in lower-claiming companies are more likely than managers in higher-claiming companies to put time limits on their responses to drivers' safety concerns. Regardless of whether there were formal policies about time limits, drivers in lower-claiming companies consistently said that managers respond quickly to any safety concerns they raise. The practice, ***all managers respond quickly to safety concerns raised by drivers*** is important to include in a safety management system. This practice can be documented as a management procedure and audited or checked by periodic staff surveys.

Evidence-based driver risk management practices (6)

Under the second grouping, driver risk management, there are six management practices. This topic is about how to manage risks associated with driver behaviour. The practices are described, together with research evidence to support each element and its measurement below.

1) Driver recruitment criteria focus on safe driving records

This study formed a convergence of research evidence to confirm the importance of using ***driver recruitment criteria that focus on safe driving records***. From a safety perspective, testing the safety risk background and risk propensity of drivers, including accident histories, has been found to be an important safety management practice (Darby et al., 2009). The recruitment of drivers by lower claimers involved more comprehensive safety focused assessment than did higher claimers' recruitment processes, including checks on driving accident histories. Higher claimers consistently checked references, but were less likely to check accident histories or safety records of drivers when recruiting. Managers from lower-claiming companies who recruit drivers check safety records and accident histories and this should be implemented. This can be recorded on personal files of drivers and audited.

2) Driver fitness is assessed to ensure drivers' abilities to safely carry out all job duties

The triangulation of prior research and Studies 2 and 3 found that while higher claimers were more likely to employ drivers over the age of 55 than were lower claimers, the important physical aspect of drivers relating to safety was their ***fitness and abilities to safely carry out all job duties***. Assessments were carried out at the recruitment stage and throughout the employment tenure for each driver to ensure that drivers are not at risk of injury through lack of fitness or capacity to carry out work.

Regardless of age, driver recruits should be assessed for their ability to carry out the tasks associated with the job in a safe manner (Guest et al., 2014). The in-depth investigation found that managers in lower-claiming companies did not rule out drivers on the basis of age, but rather assessed drivers on

the basis of their fitness for tasks required of the drivers. It was noted that some of the lower claimers employed drivers to do more than driving related work. Sometimes the work of the company involved heavy labour requiring workers with sufficient physical strength to carry out these tasks. So, while lower claimers were less likely to employ drivers over the age of 55, the rationale for employment did not exclude candidates or drivers by age, but rather an assessment of fitness for all tasks including tasks other than driving.

Driver fitness assessments can be documented at the hiring stage, and updated throughout the employment tenure. One company, Roche Australia, has implemented an online driver risk assessment program and used data from these assessments to inform policy development and targeted interventions (Murray et al., 2012). The authors concluded that the driver assessment program contributed to a 24% reduction in motor-vehicle insurance claims between 2004-2009. Tools exist to assist companies to assess and monitor driver fitness, knowledge, skills and risk propensities². These assessments can be ongoing and monitored for use in SMS improvements and auditing.

3) Drivers are paid for all hours worked, regardless of the task or activity

Convergence of prior and current study findings confirms the importance of ensuring that **drivers are paid for all hours worked, regardless of the task or activity**. Drivers not paid for all hours can tend to make up for their loss by working extra hours or extra jobs. Also, importantly, if they are paid on the basis of productivity, they may be more likely to take risks such as speeding and driving long hours (Hensher and Battellino, 1990; Mayhew and Quinlan, 2006). It is argued, in the literature cited, that paying drivers for all hours worked gives them stability and certainty of income and they are less likely to work in an unsafe manner. A number of studies into pay methods have demonstrated that the method of driver pay influences safety outcomes (Hensher and Battellino, 1990; Hensher et al., 1991; Williamson, 2007).

The Study 2 survey finding that lower claimers were more likely than higher claimers to pay drivers for the time worked instead of by the trip or truckload was confirmed in Study 3. The validation Study also confirmed that lower claimers were more likely to pay drivers for the time they spent waiting to be loaded or unloaded.

The practice, to *pay drivers for all hours worked regardless of task or activity*, should be implemented and monitored as an important measure to improve safety.

4) Training provided for drivers is based on individual tuition by experienced drivers

The SMS practice, **training provided for drivers is based on individual tuition by experienced drivers**, was found in this research to distinguish between lower and higher claimers. In general, the research results on safety benefits from driver training are mixed (American Transport Research Institute, 2008) and this research found there was little difference between lower and higher claimers in respect of the amount of safety related training provided. In fact higher claimers were found to be more likely to use standardised driver training courses. However, lower claimers were more likely to provide safety training tailored to address the specific risks of the job tasks performed and to be based on perceived drivers' skill deficits, through using experienced drivers to train or coach less experienced drivers or drivers found to have skill deficits. This approach is consistent with other research (Robotham, 2001), that identifying specific safety learning needs related to job tasks is an important training success factor. Therefore, *training provided for drivers based on individual tuition by experienced drivers* should be implemented to improve safety outcomes. The training assessments and specific training provided can be documented and audited.

5) Identified unsafe behaviours are formally investigated

The evidence from the Study 2 survey, and validated in Study 3, supports the inclusion of the SMS practice, to formally investigate unsafe behaviours. Probst and Estrada (2010) found that employees' perceptions of safety policy enforcement is a predictor of accidents and accident reporting. If discipline is not consistently applied to all drivers the actions may be seen as excuses to punish drivers for simply

² See www.virtualriskmanager.net for information about the tool used in the Roche study.

being unpopular with management. In the current research lower-claiming companies had in place more consistent approaches to safety related disciplinary investigations than higher claiming companies. The practice, **identified unsafe behaviours are formally investigated**, can be codified in company procedures and audited as well as tested through periodic staff surveys.

6) Drivers are given monetary incentives clearly linked to work safety efforts

Prior research evidence that incentives for safe behaviour and safety innovations are effective safety management practices, was supported in Study 2 and validated in Study 3. The finding was that lower claimers, and no higher claimers, give drivers **monetary incentives clearly linked to work safety efforts**. Incentives or bonuses provided for safe driving can be effective in reducing crashes (Banks, 2008; Gregersen et al., 1996) and thus costs to a company. If incentives or extra rewards are provided to drivers, they should not encourage underreporting of incidents. Positive incentives can be used to encourage employee participation in WHS activities or promote safe behaviour. The objective of incentive programs is to convey to workers that their contributions to safety improvement are valued by the organisation (Fernandez-Muniz et al., 2007).

Where lower claimers provided additional incentives for safety, the financial incentives were clearly linked to safety criteria, for example for completing job risk analyses, or end of year bonuses for safe driving. By contrast, higher claimers reported providing meals or other non-monetary extras for drivers but the link to safety criteria was unclear. In fact, a manager in a higher-claiming company, contrary to his Study 2 survey answer, advised that the BBQs provided for drivers were not meant as a safety incentive, but rather to give them an opportunity to “air their grievances.”

Whatever incentive is offered, it should be clearly linked to safety advancement. This practice can also be documented and audited.

Evidence-based safety culture management practices (2)

Under the third grouping, safety culture management, there are two distinguishing communication practices identified from the study. This Section is about managing the safety culture of the organisation. The elements of safety communication are described, together with the evidence on which they are based, in the safety management system in subsections below.

1) Managers encourage drivers to have input to WHS decision-making

The triangulation of Study 1, 2 and 3 research results strongly support the inclusion of the practice, **managers encourage drivers to have input into WHS decision-making**, in the SMS for heavy vehicle transport operations. Two longitudinal studies have shown that implementing interventions involving driver discussion groups focusing on safety risks and safety ideas can reduce crashes (Gregersen et al., 1996; Salminen, 2008), suggesting that encouragement of driver input into WHS decision-making can improve safety outcomes. Two other studies provide evidence that active participation by employees in decisions about maintaining or improving safety is associated with lower injury and accident rates (Vredenburg, 2002; Wachter and Yorio, 2014). In fact, there is evidence to suggest that the combination of management commitment and worker participation is an important measure of safety climate (Dedobbeleer and Beland, 1991). Having studied safety for remote workers, Huang et al (2013b) argue that it is especially important to have effective channels of communication when truck drivers, and other employees, work largely in isolation from managers and other workers. Given that drivers often spend long periods of time alone, they may feel that they cannot communicate about safety issues that concern them, i.e. that they must assume sole responsibility for their own and others' safety. Indeed, during the in-depth investigations the drivers in both higher- and lower-claiming companies expressed a need for this communication.

Practices like providing opportunities for driver input to safety decision-making distinguished companies with lower claim rates from companies with higher claim rates. Managers in higher-claiming companies reported that they were more likely to set criteria and rules for vehicles and drivers without consultation with drivers, than did managers in the lower-claiming companies. It was also observed in Study 3 that lower claimers seemed to focus more strongly on proactive risk assessment, ensuring that rules are agreed, and consulting drivers on safety issues. Consultation procedures and clear communication

channels across the company can ensure that changes in WHS policies and procedures involve drivers. These practices can also be documented and audited and can also be reviewed together with staff satisfaction surveys.

2) Managers take responsibility and show leadership in making safety a clear priority

While Study 1 found 30 studies demonstrating the importance of building a strong safety culture, the items in this characteristic, such as management commitment to safety, could not be accurately tested in the Study 2 manager survey. However, the in-depth investigations (Study 3) found clear and consistent differences in that, in lower-claiming companies, managers were found to take responsibility and show leadership in making safety a clear priority, whereas managers in higher-claiming companies did not.

The fact that managers in higher-claiming companies were far less consistent in self-reported safety management practices than were managers in lower-claiming companies, suggests that their knowledge of safety practices in their company was poorer, possibly due to lower commitment to safety management. Moreover, drivers in higher-claiming companies compared with drivers in lower-claiming companies were similarly far less consistent with their managers' descriptions of their companies' safety management. This could mean that communications about safety were not effective in these organisations, or that drivers do not regard safety as a priority in their company and therefore do not pay much attention to safety management practices.

It can be concluded, from the Study 3 results, that the heavy vehicle transport companies with lower insurance claim rates tended to take a more active and substantive approach to managing safety in their organisations, whereas the higher-claiming companies were found to take a more passive business-as-usual style of managing safety. Managers in lower-claiming companies were found to more fully accept responsibility for safety management, whereas many managers in higher-claiming companies complained that they had to face unfair challenges imposed by government or otherwise placed responsibility on drivers or others (e.g. customers, depot managers). Managers in five higher-claiming companies used phrases, in relation to safety management tasks, such as: "drivers are supposed to do this but they don't"; "what can I do?"; "we can't control that"; and "we just tell them to do everything by the book." In contrast, managers in lower-claiming companies check traffic and journey conditions and assist journey planning to ensure adequate rest breaks for drivers, e.g. booking their accommodation in advance.

Simard and Marchand (1995) found, in a study of 100 Canadian manufacturing plants, that a participative supervisory approach is the best predictor of workers' safety initiative behaviour. Based on their research on SMS practices in the airline industry, Chen and Chen (2014) also argue that when employees perceive that managers exhibit safety leadership they are more likely to be motivated to comply with safety rules. Evidence from the in-depth investigations found that the communications between managers and drivers in lower-claiming companies were more consistent, effective and safety focused. The safety manager and operations manager in one lower-claiming company were clearly aligned in their mutual commitment to safety – nearly finishing each other's sentences – and driver interviews supported this observation. By contrast, drivers in higher-claiming companies were not satisfied with safety communications by managers, and sometimes said that their managers contradicted safety messages provided by safety representatives or their policies, undermining their safety messages. Drivers and managers alike in higher-claiming companies demonstrated a much lesser interest in safety, with one manager saying he hardly ever thinks about safety, and managers in a two other higher-claiming company saying it would be difficult to get drivers interested in safety.

The in-depth investigation (Study 3) found that lower-claiming company managers demonstrated genuine and consistent leadership and encouragement of safe behaviours; whereas among higher claimers the managers often shrugged off their role in setting an example for desired safety behaviours. One WHS representative in a higher-claiming company advised that a senior manager didn't wear a safety vest in the depot even after he was reminded of the policy requirement to do so. By contrast a lower-claiming company manager impressed drivers, not only with strong safety leadership as a manager, but was also active in a local road safety advocacy group. A manager in another lower-

claiming company said that “zero harm” means “zero tolerance” to even minor safety breaches and provided examples of how he has conveyed this to drivers.

This practice, ***managers take responsibility and show leadership in making safety a clear priority***, is difficult to measure through safety management audits. Measurement of responsibility and leadership is more complex than the other practices covered by this research. Asking employees and drivers provides some insights but their responses may be biased. There are examples in the safety management literature from which to base tools to measure aspects of safety climate (Cox and Cheyne, 2000; Flin et al., 2000; Huang et al., 2013a; Huang et al., 2013b; Williamson et al., 1997; Zohar, 1980). A safety climate survey of seafarers found relationships between safety policy and supervisory behaviour, and in turn the perception of supervisory safety behaviour, positively related to seafarers' safer behaviour (Lu and Tsai, 2010). This suggests that efficacy of safety management leadership can be measured by the extent to which all potential safety influencers in an organisation adopt the same level of safety commitment in their practices, and are seen to do so. A robust approach to measuring management responsibility-taking and leadership might be to select some relevant, objective indicators of these practices.

How the evidence-based safety management practices combine and interact

The management practices in SMS do not exist in isolation, nor are they static (Le Coze, 2008). As shown in Chapter 2, the literature is rich with evidence of the need to see organisational systems as dynamic organisms that have interacting parts (Hale et al., 1997; Mooren et al., 2009; Rasmussen, 1997). This research identified characteristics and practices that distinguished lower- and higher-claiming companies but the combinations of other practices found to exist in both lower and higher claimers may have influenced the effects of each, or some of the practices with which they co-exist. Huang et al (2006) argued that the mediating effects of each safety control element mean that the stronger each element is, the stronger the effectiveness of other elements will be. For example, they found that employee belief that they can control their safety behaviour, in turn improves safety climate and reduces self-reported injury incidents. This means that employee belief that they can control work related injury risk strengthens the belief that the safe way to do things is the way things are done in the company, and, in turn, this influences safety outcomes. Similarly Al-Refaie (2013) showed that management commitment moderates the effectiveness of incentives, safety reporting and empowerment of employees, and that continual improvement and teamwork influence safety awareness. Safety leadership influences the effectiveness of a range of safety management practices and worker behaviours at all levels of an organisation. Based on a survey of drivers, dispatchers and safety directors of 116 US trucking companies, Arboleda et al (2003) argue that management commitment, opportunity for safety input and safety training influence perceptions of safety culture. Further, Hale et al (2010), in a study comparing companies that successfully improve safety outcomes with those that tried but were unsuccessful, found that the factors that discriminate between the two are the application of energy, creativity and support, engagement and empowerment of the workforce in a learning/change process, training and motivating managers, and using a planned and systematic approach.

Moreover, the existence of other safety management practices influences the effectiveness of different safety management practices. For example, some payment systems have been linked with poor truck maintenance practices (Thompson and Stevenson, 2014) where there is an incentive to keep trucks on the road, skipping maintenance checks, in effort to optimise income.

Further research is needed to test the specific influences, and directions of influences, of the 14 practices in the proposed safety management system. Based on the weight of the safety literature it is very likely that moderating influences among some or all of the practices exist, particularly the moderating effect of the safety culture management practices on some or all of the other practices.

The dynamic system is embodied in the proposed SMS, summarised in Figure 2, as three interacting groups of practices or *spheres*: risk assessment and management, driver risk management and safety culture management. All three spheres are interconnected. Good safety culture management is conceived as a process that continuously influences and reflects vigilance in risk management and safe driver behaviour (DeJoy et al., 2010; Lu and Yang, 2010). Based on her research into workplace safety

management, Makin (2009) argues that risk assessment and management are continuous processes of identifying potential safety hazards and influencing safety culture and worker safety practices. The management of driver related risk is another crucial sphere in the SMS. Based on a study of a large coal-mining corporation using structural modelling techniques Cui et al (2013) argue that management commitment influences employee beliefs, and that employee beliefs influence safety involvement. Safety-focused drivers play an important role in continually identifying risks and contributing to risk management solutions and in turn can influence the other spheres of practices in the system.

In this overall view of the SMS proposed for heavy vehicle transport, each of the three spheres contain components that interact with other components thus strengthening safety management effectiveness. For example, encouraging driver input in WHS decision-making makes driver incentive programs more effective. Similarly, site and job risk assessments can improve the effectiveness of safety training.

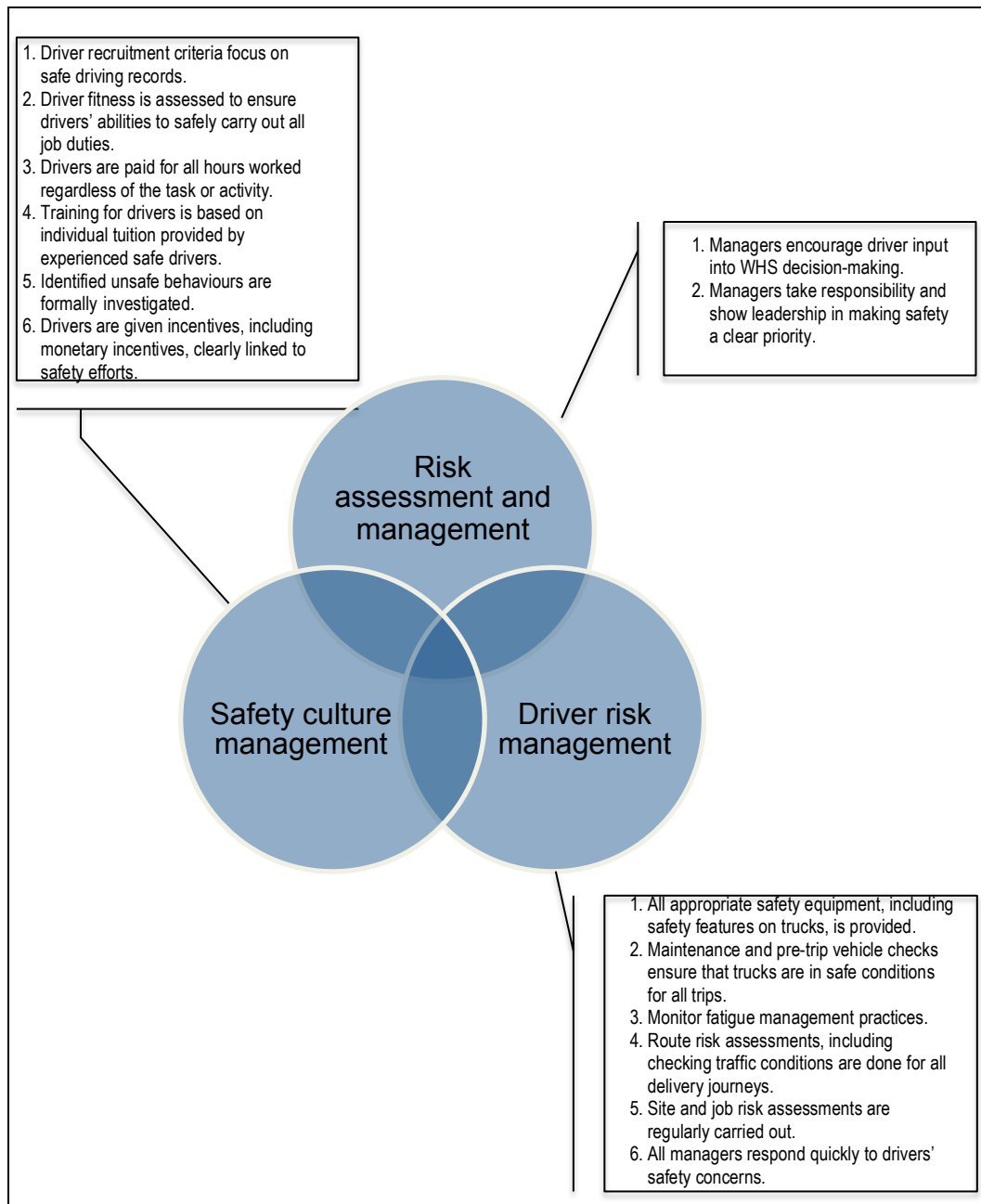


Figure 2 Model of an integrated safety management system (SMS) for heavy vehicle transport

In this model, optimal safety management involves these interlocking spheres of practices with interacting components. The model also envisages safety culture management as a continual process of demonstrating safety leadership and expectations that in turn encourage vigilant risk assessment and

amelioration. Other research has demonstrated that the strength of safety culture and communication is likely to intensify the effectiveness of driver risk management (Al-Refaie, 2013). Moreover, Al-Raife concluded that the management of driver risk assists to build a stronger safety culture and enhance risk perceptions and safety innovations. Based on research findings in Portuguese chemical companies Silva and Lima (2005) argued that an ongoing risk assessment process helps to build strong safety awareness by managers, drivers and others in the organisation, as well as contributing to learning and development that, in turn, strengthens safety culture. Finally, the findings of safety management research (Leveson, 2004) in the aerospace industry suggest that risk assessment and management, driver risk management and safety culture management practices are continuously changing and interacting with one another. Whilst it is recognised that there are important differences in the work environments experienced by truck drivers compared to workers in chemical or nuclear plants, the research (Al-Refaie, 2013; Arboleda et al., 2003) suggests that building a strong safety culture intensifies the effectiveness of other safety practices.

The scientific research literature, described in this section, provides evidence that there are synergistic effects of combining safety management practices. The yet-untested relationships between safety outcomes and combined safety management practices could provide further evidence that the SMS would operate as an integrated system with interacting elements.

General discussion

The genesis of this work was recognition that despite high levels of safety risk in the heavy vehicle transport sector, very little research had been done to test the efficacy of safety management practices in either in this sector or any other sector.

The research for this thesis comprised three distinct studies that built an evidence base for the development of a safety management system (SMS) for heavy vehicle road transport operations. The method used in the identification of important safety management practices was to distil from the scientific literature positive relationships between safety management practices and safety outcomes, then to work backwards looking at good and poorer safety performers and seeing what combinations of safety management practices distinguished between them in a sample of heavy vehicle truck operators. The synthesis of knowledge gained through the studies together with an examination of the road freight transport sector enabled development of an SMS particularly suited for this industry. Each of the fourteen practices of the proposed SMS is justified by original research (Study 2 and Study 3), together with evidence from the scientific safety literature. The unexpected findings, where what were thought to be good safety management practices were found to be more common amongst higher insurance claimers than lower claimers, suggest that practices like, having safety accreditations, safety policies and training, are not sufficient for the achievement of good safety outcomes – and indeed could mislead regulators and customers that the company has good safety outcomes.

The proposed SMS recognises the interplay of applying the safety management practices together interactively. In other words it is hypothesised that the synergistic effects of risk assessment management, driver risk management and safety culture management elements working together mean that comprehensive implementation of the SMS is likely to be more effective than implementing one or several of the elements alone. However, this was not tested in this research. Testing the SMS on a poorer (safety) performing company to see if its crash outcomes improve was beyond the scope of this thesis. It will be up to other researchers in a future research project to test the SMS. The benefits of this research have been the identification of a set of safety management practices that were shown to distinguish between lower and higher-claiming heavy vehicle transport operators. This provides a more targeted approach to safety management improvements.

Limitations

Limitations relating to data collection and analysis in Studies 2 and 3 should be noted. There were significant challenges in recruiting participant companies for the study, resulting in the inability to rely on formal tests of statistical significance for confirming survey results. However, tests for effects sizes (Olivier and Bell, 2013) to provide guidance on the robustness of the survey findings were carried out.

Another limitation to the survey was that, like most similar studies, it relied on self-reported data provided by managers about their safety management. This was recognised as a potential problem from the outset. In part for this reason the study included a validation process following the survey in the form of an in-depth investigation into a sample of survey participants. That investigation specifically sought to identify evidence to validate the accuracy of the answers provided in the survey.

Due to the small survey sample size, for many purposes it was not possible to analyse the survey data within size groupings (small and large fleet operators). However, the in-depth investigations found that while smaller companies had less detailed formal systems generally, the more distinguishable safety management characteristics were the ways in which drivers perceived the importance that management placed on safety, regardless of company size. Otherwise, the differences found were more attributable to claim rate performance than size of company.

It is also noted that as the participants were all companies that were operating only in Australia, it is not known if the findings and specific outputs of the study will apply in other countries. The study has particular currency in Australia where regulators and industry are grappling with the transport regulations that do not require auditable safety management systems as are required in other countries, such as the USA, including regulation of 'chain of responsibility' whereby operators are not told how they should implement safety management practices, but instead must show a 'duty of care.' However, the study can also assist to inform the efficacy of practices prescribed in existing auditable safety management systems or safety management regulatory requirements. The nature and scope of this type of study, where there were many variables to consider within a complex system, did not permit a detailed examination of each of the safety management practices and the effects of applying these practices. This was deliberate, as the unit of study was the company and not an evaluation of management action or company practices within a single company.

Empirical testing of the SMS

The research presented in this thesis has led to the development of an evidence-based framework of practices of an SMS this is likely to be effective in improving safety and crash outcomes. Currently, a project to empirically test the safety management system has been commenced by the University of New South Wales. The SMS will be trialled in companies that operate 10-50 heavy vehicles for transport of goods, equipment and/or other materials under hire and reward conditions. These types of companies were chosen to produce a relatively homogenous sample for the evaluation. Very small companies that might have limited resources to undertake the study and very large companies that might have difficulty implementing change within the study timeframes will not be recruited. The intervention will be applied in lower safety performing companies, using the safety measure of insurance claims per truck. This criterion is similar to that used in the study presented in this thesis.

The trial study will be an intervention-control group design conducted over two years. Baseline measures of practices and outcomes will be taken of all the companies during a 'pre-intervention' (baseline) period at the start of the first year. The companies will then be randomly assigned to an intervention or a 'wait' control group, with the constraint that there is a similar mix of larger and smaller companies in each group. The plan is for the first intervention group to receive the intervention during the first year. The intervention will involve provision of an expert advisor for a period of three months to assist the managers to plan and carry out changes to safety management practices consistent with the validated characteristics and practices identified through this research. At the end of the first year, practices and outcomes will be measured again in all companies. Half of the control group will then be selected randomly to receive the intervention during the second year. At the end of year two, all the companies will be measured again. This design permits an analysis of both short and longer-term effects of the intervention. At the end of the study the remaining control group companies will be given the intervention. The main components of the intervention are an initial assessment of each company's practices relative to the set of characteristics identified in the earlier studies, structured assistance in identifying improved practices suitable for each company, development and monitoring of an implementation schedule, and access to ongoing advice about implementation. Using the evidence-based safety management system, further trial research in the transport sector, as well as other industry sectors, is encouraged.

Recommendations for further research

This research found that a number of safety management items were not confirmed as characteristics that distinguish between lower and higher truck insurance claimers because the managers did not provide sufficient evidence in Study 3 to validate their survey answers. There could be benefit in testing these characteristics in future studies. The findings that were unexpected, based on a review of findings from prior research, particularly the finding that higher claimers were more likely to have fatigue risk management policies and training, certainly warrant further investigation, although one interpretation of this is that these practices are not important safety management practices on their own. But this interpretation should be tested to learn more about what is particularly important in managing fatigue risk in truck driving.

Additionally research to test and refine relationships between elements in the model is recommended. The big challenge is to find methods to research relationships in a non-linear dynamic model. For example, the provision of monetary incentives to drivers might strengthen the site and job risk assessment element of the SMS, which is also influenced by the extent to which managers encourage driver input into WHS decision-making, but these relationships need to be tested.

As injury events occur from a set of interacting causes, prevention may require sets of interacting safety management practices. In other words, the whole is greater than the sum of its parts – and choosing only one or two practices to implement is not likely to be as effective as choosing a system of interacting practices. This is especially the case for the dynamic and complex operations that characterise heavy vehicle transport operations. In this industry work practices do not generally involve only predictable, repetitive tasks. They are instead practices in which the changing environment and safety challenges demand an ability to make risk decisions quite frequently throughout the work process. For example, a driver must constantly select optimal driving speeds, and constantly decide whether s/he is mentally or physically fit enough to continue to make safe decisions. Further research into the specific work and decision-making processes undertaken by truck drivers would assist to gain insights into the risk processes involved in truck driving. A naturalistic driving³ study involving truck drivers would be helpful.

Implications for industry, regulators and insurers

Notwithstanding the limitations mentioned above, the development of an evidence-based safety management system suitable for use by heavy vehicle transport operators potentially could assist large and small trucking companies and others that operate heavy trucks to reduce safety risks by implementing the system. The results of this research could be presented in public forums, and companies operating heavy vehicles may wish to consider the possible uses of the findings.

If the empirical testing of the SMS, described above, finds that implementing the SMS does improve safety outcomes, industry and government safety management schemes could then be refined and/or elements of existing schemes supported. Ultimately, this safety management system, made freely available, could assist heavy vehicle transport operators to comply with their chain of responsibility obligations. This in turn should assist regulators to know what to look for to determine if companies are meeting their duty of care responsibilities. Similarly, insurance companies that provide truck insurance may be in a better position to determine risk propensities of current and future policyholders and to suggest interventions to improve safety performance and thus reward companies that implement such a system with lower premiums.

Changing the paradigm

This study set out to develop a safety management system through a research process. Most would say that the bottom line for safety interventions is absence or reduced incidence of harmful events (Nilsen et al., 2004). The approach used in this research was to start from outcomes (comparative insurance claim rates) and work back to the characteristics that distinguish good and poorer safety performing companies in order to design interventions that should improve safety outcomes. It aimed to find

³ Naturalistic driving studies involve instrumenting vehicles with monitoring equipment including video cameras and other data collection devices to enable an examination of driving behaviours.

characteristics that distinguished between companies with better safety performance and companies with poorer safety performance. It did not seek to test the specific effects of particular management practices, but rather the approach was to find as many elements of safety management that characterised good safety performers and did not characterise poor safety performers. Looking at safety management more holistically allows the identification of sets of important safety management practices.

This contrasts with the traditional road safety dissection of contributing injury factors when crashes occur and then planning individual countermeasures to address the individual contributing factors (Salmon et al., 2012). Road safety research has taught us that combinations of countermeasures such as public education and enforcement are more effective than doing one without the other (Elliott, 1993; Lewis et al., 2007). However, by and large, interventions are planned and implemented in a silo-fashion to address road environment factors, vehicle and equipment factors and human factors as separate problems. That is, traditionally, road safety researchers and practitioners have approached road injury hazards as individual problems and have in general failed to acknowledge the dynamic interactions among them.

Taking a *systems* view, road injury hazards can be understood as a set of interacting variables that require interdependent actions to respond effectively to these risks instead of the traditional approach of a group of individual problems with sets of single interventions. This relatively new systems approach to road safety reflects a greater understanding of the complex and integrated nature of human interaction with the environments in which they operate within (Salmon et al., 2012). However, the systems approach has not been fully applied in road safety.

There are parallels between public road safety and workplace safety but up until now, the two fields have taken different approaches to analysing and managing risk. Just as road rules without enforcement are not as effective in encouraging safe behaviour so too are safety policies without consistent corrective actions in the workplace from WHS regulators. Reason (2000) speaks of active failures and latent conditions (caused by human decisions prior to the event). In this way, injury events are understood as resulting from inadequate injury defences in a system or process. Latent conditions can be addressed before proximal risk factors have a chance to manifest. For example, we know that unsafe driving speed is a major factor in fatal crashes, but we are only starting to understand what can be done at a systemic level to change the conditions that encourage speeding. The decision by a truck driver to drive at unsafe speeds, is in part, influenced by organisational pressures and financial conditions and decisions – both at a personal and at a company level. Indeed, this study has reinforced the evidence that payment for work done influences safety outcomes in the trucking industry. In this case, the choice of driver remuneration method is a systemic response to the risk of speeding.

The 'safe system' principle adopted to underpin road safety strategies in Australia and in other jurisdictions implies that 'systems thinking' is starting to gain attention by road safety researchers and practitioners. The idea is for the road traffic system to be designed and managed to eliminate inherent injury risks, largely by making crashes more survivable. The current road safety thinking is that it is not possible to perfect human road users such that crashes can all be avoided through consistent correct decision-making. In effect, the road safety systems approach is currently less concerned about preventing crashes, than protecting road users from being harmed in the event of a crash. The prevailing objective of the New Car Assessment Program (NCAP) is to ensure vehicle occupants are cushioned (by seatbelts and airbags) to prevent them from harmful impacts within the vehicle when it crashes. NCAP is only now beginning to test the efficacy of crash avoidance systems as well. Similarly the international Road Assessment Program has focussed more on developing roads and roadsides that are forgiving of human error. The idea is that human error is assumed to be a given condition. The mixed results in the literature about whether driver training can reduce crashes reinforces the notion that skilled and experienced drivers are unlikely to become less error-prone through educational measures. Therefore the behavioural countermeasures that are used by road safety authorities are largely focused on punitive actions for traffic violations. Developing and maintaining a road safety culture is rarely even discussed in this field, unlike the WHS field.

In workplace safety, safety culture and system safety is more fully addressed with accident prevention as well as mitigation strategies. These strategies involve efforts to reduce the likelihood of human error

as well as safeguarding the work environment and work process such that workers do not get harmed in accidents by managing injury risks in the work system. This study has attempted to show how a systems approach can be applied to road safety where government authorities, as well as companies, are the system managers ultimately responsible for ensuring safety within the system. Moreover, if an incident occurs these authorities, companies and managers must ensure that the incident is not repeated.

The study may also provide a new impetus to shift the road safety paradigm to a systems analytical approach.

Conclusions

The overall aims of this research were met. Through a three-staged research process the study has identified the distinguishing characteristics of heavy vehicle transport operating companies with good safety records and those with poorer safety records, and developed a safety management system suitable for heavy vehicle transport operations. This study has done all it can to ensure that the evidence on the components of a successful SMS for heavy transport is as strong as possible. This was done by:

- Basing identification of practices on the solid foundation of previous research;
- Identifying practices that distinguish lower and higher performing companies;
- Checking the validity of these identified practices; and
- Identifying some practices that might not actually contribute to better safety despite previous research that suggests they should be included in an SMS.

There is strong evidence that fully implementing the 14 safety management practices of the proposed safety management system should improve safety outcomes in companies that operate heavy trucks. The effectiveness of implementing some, but not all, of the recommendations may reduce the ability to achieve optimal outcomes as many of the elements, and groups of characteristics, can influence the effects from other elements.

Developing an evidence-based safety management system advances the field of occupational safety, particularly as it relates to work related road safety. It provides a new model for exploration, testing and refinement. This ultimately is likely to result in fewer work related road injuries in the heavy vehicle transport sector, as well as translation and application in other work related road safety contexts.

While no one has yet applied an SMS approach to road safety, and demonstrated that the method can reduce crashes and associated road trauma, there is reason to believe that this would be worthwhile. Now there is an evidence-based SMS tailored to the heavy trucking industry to trial. The planned study involving the implementation and evaluation of this SMS in companies with poor safety outcomes is expected to further confirm the effectiveness of the new SMS.

Finally, this work has challenged traditional approaches to road safety analysis and intervention planning in fundamental ways. Analysis of this study's findings indicates that a more integrated and dynamic model is needed, to apply to road safety research and countermeasure planning, using a systems approach.

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