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Associations between task, training and social environmental factors and error types involved in rail incidents and accidents

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ABSTRACT

Rail accidents can be understood in terms of the systemic and individual contributions to their causation. The current study was undertaken to determine whether errors and violations are more often associated with different local and organisational factors that contribute to rail accidents. The Contributing Factors Framework (CFF), a tool developed for the collection and codification of data regarding rail accidents and incidents, was applied to a sample of investigation reports. In addition, a more detailed categorisation of errors was undertaken. Ninety-six investigation reports into Australian accidents and incidents occurring between 1999 and 2008 were analysed. Each report was coded independently by two experienced coders. Task demand factors were significantly more often associated with skill-based errors, knowledge and training deficiencies significantly associated with mistakes, and violations significantly linked to social environmental factors.

1. Introduction

From January 2001 to December 2010, 392 fatalities have occurred in Australia from rail accidents (Australian Transport Safety Bureau, 2011). In the year 2009, railway accidents in European Union countries lead to 1391 deaths, although a relatively small number of these fatalities were passengers (European Railway Agency, 2011). Rail may not experience the high numbers of fatalities seen in other industries such as road transport (see Bureau of Infrastructure Transport and Regional Economics, 2010), however, as a complex safety critical industry with a considerable passenger transport component, there is an ever-present risk of a catastrophic event occurring. This risk has been realised in numerous accidents overseas and locally and motivates the need to better understand why these accidents occur, and how they can be prevented.

Applying systems theory to understanding accidents facilitates a broad and holistic perspective of problems: from the actions of the individuals involved, to the organisational processes and management decisions that affected the outcome, as well as the wider social and environmental context such as community expectations and government influences. A systems approach has been demonstrated to provide a valuable basis for the analysis of accident data (see for example, Hobbs and Williamson, 2003; Li and Harris, 2006).

Reason's model of accident development in organisations (the 'Reason model', 1990, 1995, 1997, 2008) is a systemic model that is widely accepted in the accident prevention field and has been highly influential since it was first published (Hauer, 2010; Hayward et al., 2008). The model acknowledges the role of human error at all levels of the organisational system, and the futility of focusing accident investigations only on errors by front line personnel. The Reason model has informed the development of many tools and methods utilised in system safety analyses such as the Incident Cause Analysis Method (ICAM, De Landre et al., 2007), the Human Factors Analysis and Classification System (HFACS, Wiegmann and Shappell, 2003) and the Contributing Factors Framework (CFF, Rail Safety Regulators' Panel, 2009). These approaches typically involve identifying errors or deficiencies at different levels of the system such as the individual level, the local workplace level, the organisational level and the external environment.

2. Previous research exploring contributing factors and their associations

Previous studies that have aimed to identify contributing factors to rail accidents have been limited to reporting only frequencies of contributing factors based on investigation of incidents and analysis of the factors identified (Reinach and Viale, 2006)

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or retrospective analysis of a sample of accidents (Baysari et al., 2008; Edkins and Pollock, 1997; Rail Safety and Standards Board, 2009). Although knowledge of the frequencies of different error types and other contributing factors is useful in understanding the issues associated with that sample of accidents or incidents, which might be generalisable to operations in that industry, knowing the associations between factors would be especially informative. Information about the associations between factors enables practitioners to gain an understanding of systemic impacts on individual behaviour, which are more likely to apply across industries, or across organisations (Hobbs and Williamson, 2003).

Analyses of associations between factors involved in accidents have occurred in studies of aviation (Li and Harris, 2006; Li et al., 2008), aviation maintenance (Hobbs and Kanki, 2008; Hobbs and Williamson, 2003) as well as occupational accidents (Feyer et al., 1997). This research has demonstrated that a particular organisational deficiency will often not affect all error types equally. Such research has not previously been conducted on data from rail transport incidents and accidents. Further, no studies conducted in any industries were identified that had formulated and tested hypotheses. Rather, previous research in this area has tended to be exploratory only.

The current study involved the development of specific hypotheses about associations between particular local or organisational factors and error types based on theories of information processing and human performance. These hypotheses were tested in an applied setting, through retrospective analysis of rail accident investigation data.

3. Predicting associations

Previous research (e.g. Hobbs and Williamson, 2002; Li and Harris, 2006) and theories of human behaviour would support the notion that certain factors will be associated with these different classifications of unsafe acts. The following discussion will outline the associations that would be expected between factors within the workplace or organisational system, and the three types of unsafe act proposed by Reason (1990): skill-based errors, mistakes and violations.

3.1. Errors of skill-based processing

Skill-based processing is generally utilised during familiar, well practiced tasks (Rasmussen, 1982). Performance at this level can be described as automatic or outside conscious control, but requires routine evaluations and checks by a supervisory attentional system to ensure that actions are being executed correctly (Norman and Shallice, 2000; Reason, 1990). It is generally accepted that information processing resources, including attention, are limited in their capacity (Cohen et al., 1990; Fougnie and Marois, 2006; Wickens, 2002; Wickens and Hollands, 2000). Thus, Reason suggests that additional tasks performed concurrently with a skill-based task, or distractions that interfere with routine attentional checks on performance, can induce errors (1990). These errors take the form of slips of action or lapses of memory.

Research by Botvinick and Bylsma (2005) demonstrated that brief interruptions during a routine, sequential task led to slips of action. Other studies have found the incidence of errors increasing with increasing workload (Langdan-Fox and Empson, 1985), and that skill-based errors and failures of attention were frequently implicated in rail accidents (Edkins and Pollock, 1997).

Hypothesis 1. That task demand factors (such as high workload, distractions and time pressure) would be associated with skill-based errors.

3.2. Errors of rule- or knowledge-based processing

Mistakes can occur in either rule- or knowledge-based processing, generally at a more conscious level. An example of a rule-based mistake would be the application of a principle in an unsuitable situation, culminating in a negative outcome. When the situation is novel, and no applicable rule is available, processing occurs in the knowledge-based domain in which more generic reasoning skills are applied to reach decisions. Errors of rule- and knowledge based processing come about when an individual has either no schema available to apply to the situation or applies the wrong rule or schema (Rasmussen, 1982; Reason, 1990). Schema is developed through experiential learning which could occur through repeated exposure to a particular situation, or through learning opportunities provided in training programs. Mistakes may occur if training fails to provide experience in dealing with unfamiliar situations, or fails to deliver a broad range of experiences to provide an understanding of when rules apply, leading to flawed interpretations of a situation and poor decision making. Retrospective analyses of accidents have found knowledge-based errors to be significantly associated with training (Hobbs and Kanki, 2008; Hobbs and Williamson, 2003).

Hypothesis 2. That a lack of knowledge, task inexperience and deficiencies in training would be associated with mistakes.

3.3. Intentional violations

Violations are distinct from errors in that they are intentional (Reason, 1990, 2008). Intentional actions, according to the theory of planned behaviour (Ajzen and Fishbein, 2005), can be predicted by attitudes of individuals, subjective norms and their sense of control over their actions. When the norms of a workplace condone, or even encourage, violations for example, individuals should be more likely to engage in this behaviour. Social norms and workplace culture can also influence the attitudes of individuals about violating.

Research into violations in a rail context found that organisational culture affects organisational factors (including the quality of rules, degree of employee participation in rule development and amendment, quality of training and monitoring practices) and situational factors, as well as group norms in the local workplace which, depending on individual differences, provoked violations (Lawton, 1998). The association between norms and violations has been supported by analysis of an aviation maintenance incident sample (Hobbs and Kanki, 2008). Further, a study of violations in the medical setting found that anaesthetists were most influenced by normative beliefs when choosing not to violate guidelines (Beatty and Beatty, 2004).

A study of violations in aviation maintenance utilised a survey methodology to explore the applicability of the theory of planned behaviour, modified with the addition of management attitudes and the substitution of perceived behavioural control for work pressures, to this context (Fogarty and Shaw, 2010). The results of the survey generally supported the model's predictions, with the additional variable of management attitudes found to be particularly important as this affected the attitudes of workers, as well as workplace norms and work pressures. The findings strongly supported the role of group norms in influencing violations while the variable of workplace pressures was not as well supported in that it affected intentions to violate but did not directly influence the commission of violations. These results support the notion of violations being associated with social norms, and not with workplace pressures such as time pressure.

However, a review of research into violations has concluded that many influences at different levels of the organisational system could contribute to these behaviours and that more research is needed to determine which, if any, workplace variables are consistently associated with violations (Alper and Karsh, 2009). Thus, the current study aimed to further examine this relationship and predicted that social environmental factors, particularly social norms, would be associated with violation behaviours.

Hypothesis 3. That social environmental factors would be associated with violations.

4. Method

4.1. Data sources

All investigation reports into Australian rail safety incidents and accidents between 1 January 1999 and 31 December 2008 that had been released prior to 30 June 2009 were considered for inclusion in this study. These investigation reports were downloaded from the websites of independent statutory investigation bodies, being the Australian Transport Safety Bureau (ATSB), the Victorian Office of the Chief Investigator (OCI) and the NSW Office of Transport Safety Investigations (OTSI) as well as Queensland Transport (QT), the rail safety regulator for Queensland which sometimes conducts, and publishes the findings of, systemic investigations. Two published NSW Government inquiries into accidents were identified for coding. A search was also conducted of the records of Transport Safety Victoria (the Victorian rail safety regulator) for investigation reports of that time period that had been conducted by accredited rail operators and provided to the regulator before 30 June 2009. All investigations had been conducted by trained investigators employed by the investigatory agencies or rail operators.

The rail industry in Australia is disaggregated, with numerous organisations involved in delivering rail operations in each state, and some operating across the country. As such, the sample of reports was associated with more than twenty rail organisations including those that operate rail services, those responsible for managing infrastructure, and contractor organisations providing construction and maintenance functions.

4.2. Analytical method

The CFF (Rail Safety Regulators' Panel, 2009) was used to classify the contributing factors identified within the investigation reports. The CFF is a framework and data set, based on the Reason model which provides codes developed specifically for the Australia rail industry. It enables the collection of aggregate data about contributing factors over multiple accidents.

The framework consists of three categories of contributing factors: Individual/team actions, Technical failures and Local conditions/organisational factors. The relationships between these categories are illustrated in Fig. 1. For example, Local conditions/organisational factors can directly lead to the incidence of errors and violations by frontline staff or they can represent failures in defences put in place by the organisation to avoid or contain the accident (shown as vertical lines in Fig. 1). The structure of the CFF differs slightly to Reason's original formulation with the addition of technical failures as direct contributors to accidents.

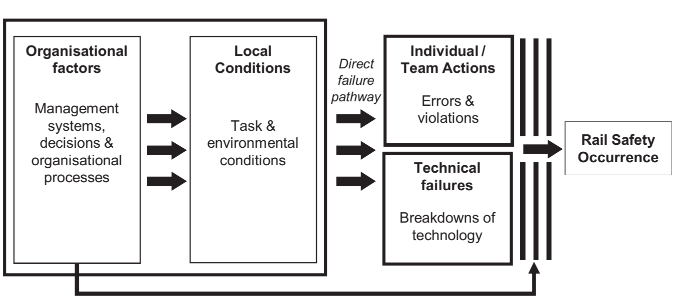

Fig. 1. The structure of the CFF, adapted from Rail Safety Regulators' Panel (2009) and Reason (1995).

For each category in the CFF, codes have been developed that are applied to each contributing factor identified in an investigation report. For the Individual/team action category, the codes differentiate the role of the person/s who performed the activity in which an error or violation occurred, the activity that was undertaken, and the error or violation type. As the CFF only includes three codes for error/violation type (error, violation or unknown error/violation), the error code was replaced with three more detailed error codes: skill-based error, mistake (including both rule- and knowledge-based mistakes), and other error.

The data coded for Technical failures includes the component that failed, the mode of failure and the stage of the system lifecycle in which the failure originated. However, as the current study is concerned with associations between error types and factors in the local workplace and organisation system, technical failure data were not analysed.

In terms of the Local conditions/organisational factors, the CFF contains 11 higher level codes (such as personal factors, procedures, organisational management) with a small number of keywords available under each to further specify the nature of the contributing factor.

4.3. Case selection

An initial review of each investigation report was conducted prior to coding. To be included in the data set for analysis, a report was required to contain at least one or more contributing individual or team action or one local condition or organisational factor, as defined in the CFF. This criterion was applied to support the focus of this investigation, namely on errors and violations committed by workers within the rail industry and the systemic or organisational factors contributing to these errors or to accidents generally. Incidents and accidents involving level crossings were excluded from the analysis because of the specific issues around the road–rail interface, which would be better analysed in a separate study focusing on these issues.

4.4. Procedure

Following a methodology used in similar previous studies (e.g. Lenné et al., 2006; Li and Harris, 2006; Tvaryanas et al., 2006), investigation reports were independently coded by two experienced coders with consensus being reached for the final data set. All investigation reports were coded by one primary coder and independently coded by a second coder from a pool of five secondary coders. The primary coder had extensive experience applying the CFF to investigation reports prior to the commencement of the study. All other coders received training prior to being involved in the study.

The procedure for coding involved documenting information about the accident and incident, including a description of what occurred, the location, date, and occurrence type. Coders then reviewed the section of the investigation report outlining the findings and reviewed and coded each contributing factor. Consistent with the CFF coding methodology, a factor was identified as a contributing factor only if it met the definition of "any element of the occurrence, which if removed from the occurrence sequence, would have prevented the occurrence or reduced the severity of the consequences of the occurrence" (Rail Safety Regulators' Panel, 2009, p. 8).

Each contributing factor was then classified as an Individual/team action, a Technical failure or a Local condition/organisational factor, and the relevant codes were then applied. For the local conditions and organisational factors, a detailed keyword was assigned to the factor. The coding was accompanied by a text description of the finding. Coders would often refer to other sections of the investigation report to fully understand the background to the finding and assist in choosing the correct codes.

For a small number of occurrences, investigation reports by two different organisations were available for analysis. In these cases both reports were reviewed but coding was based on investigations conducted by independent investigatory bodies such as the ATSB, OCI or OTSI. These bodies generally have access to superior resourcing for the conduct of these investigations and, because of their independent status, had no interest in the outcome of the investigation. Findings from the other report were coded if they were consistent with the accident sequence determined by the independent investigation, but had not been identified by that investigation.

Disagreements about the contributing factors selected for coding and the CFF codes chosen were resolved through case by case discussion, and an agreed code was entered into the consolidated file for analysis. If the disagreement could not be resolved by the two coders, a third party expert would be sought to provide advice. However, this third party consultation was only required for the interpretation of contributing factors on approximately four occasions. The final data utilised for analysis was that agreed and documented in the consensus meetings.

Following application of the CFF, coders jointly discussed and documented which organisational factors related to which errors for each report.

4.5. Inter-rater reliability

There were two sources of possible discrepancy between coders during the initial coding process. Thus, two analyses were performed to explore inter-rater reliability. Firstly, an analysis was performed to ascertain the level of agreement regarding the identification of factors to be coded. Factors that were identified by both coders, and were coded in the same category of the framework (i.e. both coders decided that the factor was either an Individual/team action, a Technical failure or a Local condition/organisational factor) were designated as agreements. These agreements were calculated for each coding pair and ranged from 25% to 75.82%. Secondly, Cohen's kappa was used to determine the reliability of the application of the coding framework to those agreed factors. This was completed for four of the five coding pairs, as one pair had coded only a small number of reports (two). The reliability coefficients obtained for the other four pairs were .48, .69, .71 and .88. According to Landis and Koch (1977), these coefficients represent moderate to almost perfect agreement.

As noted above, any disagreements about the contributing factors identified or the codes selected were resolved through case by case discussion, and the final data used for analysis had been agreed by both coders.

5. Results

In total, the coded data from 95 investigation reports were utilised in the analysis. The accidents and incidents reported entailed collisions (33.68%), derailments (42.11%), signals passed at danger (13.68%), safeworking rule or procedure breaches (8.42%) and equipment failures (2.11%).

Table 1
Frequencies and percentages for error/violation type.

Error/violation type	N	%	Example contributing factor allocated this code
Skill-based error	17	10.1	A train crew member operated the push button that had the effect of changing the points. He had no intention of performing the action at that time, but pushed the button in an 'automatic' fashion, out of habit.
Mistake	36	21.3	The driver approached the signal at too fast a speed with no room for error. The driver was experienced driving trains with more responsive braking capability.
Other error	34	20.1	The controller did not instruct the signaller to place blocking facilities on the starting signal in order to prevent the train from departing.
Violation	23	13.6	The lead shunter authorised conflicting shunt movements to occur. This informal work-around for shunting operations was used regularly.
Unknown error/violation	59	34.9	The train driver entered the siding and continued along it at speeds above those permitted. Given the wet conditions and the general degradation of braking performance expected in such circumstances the driver did not operate the train in a manner appropriate for the prevailing conditions.
Total	169	100	

5.1. Frequency of error types

The agreed coded data were collated and frequencies of different categories were determined. Where an Individual/team action was identified as a contributing factor, the Error/violation type was coded. The frequencies and percentages for each error type coded are displayed in Table 1.

The most commonly coded error type was unknown error/violation, which was chosen where the report did not contain sufficient information to determine whether the action taken was an error or a violation. The next highest category was other error, where the action represented an error but not enough information was available to determine which type of error. Violations were the next highest category, followed by mistakes and then by skill-based errors. Train crew were the employee group who committed the most errors and violations and the most frequent activity in which the error or violation occurred was when operating equipment, such as when driving a train or using signalling equipment.

5.2. Frequencies of local conditions and organisational factors

Frequencies for each of the categories of local conditions or latent organisational factors were also identified. These are shown in Table 2.

The management of the organisation (in particular issues around risk or change management), issues associated with the functionality of equipment, plant or infrastructure and problems associated with procedures were the highest frequency high level factors.

Approximately one third (38.31%) of the 402 local conditions and organisational factors identified were associated with an error or violation, whereas the remaining 61.69% were not. Further, almost half (48.52%) of the 169 errors and violations identified did not correspond to an identified contributing factor.

5.3. Interactions between factors

Although the frequencies associated with all Individual/team action and Local condition/organisational factor categories

Table 2
Frequencies and percentages for local conditions and organisational factors.

Local condition/organisational factor type[a]	*N*	%	Example contributing factor allocated to this code
Personal factors	18	4.5	The driver had a maximum of four and a half hours sleep between shifts and was fatigued and probably experienced microsleep episodes on the approach to the signal.
Knowledge, skills and experience	24	6	Both crew members had more than 20 years train driving experience. However, both had limited experience working as a two-crew team on shunt locomotives.
Task demands	15	3.7	The train controller was pre-occupied with the requirement to reschedule train movements elsewhere, due to a points failure.
Physical environment	36	8.9	The welder's ability to hear the approaching excavator would have been affected by the noise associated with the cutting and welding tasks he was performing as well as the operation of trains on the adjacent lines.
Social environment	18	4.5	The track machine operators and supervisors had become de-sensitised to the importance of a stop aspect on a protecting signal, due to the habitual authorisation to pass these signals at stop. Train controllers had been insisting on allowing track machines and road-rail vehicles to pass signals at stop contrary to the rules.
Procedures	59	14.7	The safeworking rule was open to interpretation.
Training and assessment	19	4.7	There was a lack of adequate training documentation and associated training to instruct employees in safe shunting procedures.
Equipment, plant and infrastructure	84	20.9	Because of the way foot pilot valve was designed, it did not activate when the driver was in an impaired state.
People management	29	7.2	The train guard was suffering fatigue as a result of his rostering.
Organisational management	90	22.4	A formal risk assessment of the impact of the procedural changes was not completed.
External organisational influences	10	2.5	The Regulator reduced audit activity due to a lack of operational resources.
Total	402	100	

[a] Note, each Local condition/organisational factor has more detailed keywords associated with the factor. This level of detail has not been included.

Table 3
Contingency tables for hypothesis testing.

Skill-based errors and task demands[a]	Skill-based error	Not skill-based error	Examples of associated factors
Task demand factor	84.62%	15.38%	Task demands factor – Driver was distracted by a passenger on the platform associated with Skill-based error – Driver forgot to re-check the signal and continued past the signal while at stop
Not task demand factor	22.08%	77.92%	
Mistakes and knowledge and training[a]	**Mistake**	**Not mistake**	**Examples of associated factors**
Knowledge or training factor	68.42%	31.58%	Knowledge factor – Maintenance personnel lacked experience in unloading ballast associated with Mistake – The method chosen by the maintenance personnel to unload the ballast led to an excessive volume of ballast being discharged
Not knowledge or training factor	33.80%	66.2%	
Violations and social environmental factors[a]	**Violation**	**Not violation**	**Examples of associated factors**
Social environmental factor	87.50%	12.5%	Social environmental factor – A production culture of '*getting the job done*' existed within the group associated with Violation – A supervisor did not hold a pre-work briefing because it would delay the start of the project
Not social environmental factor	21.95%	78.05%	

[a] Statistically significant, $p < 0.01$.

contributing factors are reported above, only those codes relevant to the study hypotheses were analysed for interactions.

Fisher's exact probability test was used to test the hypotheses due to small sample sizes in some cells of the 2×2 contingency tables created. This test does not generate Type I errors even when the sample size is limited. The contingency tables are shown in Table 3.

This analysis showed that, of the errors linked to task demand factors (keywords of distraction, high workload and time pressure), 84.62% were skill-based errors. Further, of errors not associated with task demand factors, only 22.08% were skill-based, $p < 0.001$ (Fisher's Exact Test, 2-tailed). Hence, consistent with Hypothesis 1, when the factors related to task demands, the likelihood of skill-based errors increased.

The second hypothesis considered whether deficiencies in knowledge and training (all keywords within the higher level codes of Knowledge, skills & experience and Training & assessment) were related to mistakes. Of the errors that were linked to knowledge or training codes, 68.42% were mistakes. Of the errors that were not linked to knowledge or training, 33.80% were mistakes, $p = 0.009$ (Fisher's Exact Test, 2-tailed). Therefore, consistent with the second hypothesis, when knowledge and training factors were identified, mistakes as opposed to other errors or violations were more likely.

Finally, of the errors related to social environmental factors (keywords of norms and values, and team climate), 87.50% were violations, whereas of those errors not associated with social environmental factors, 21.95% were violations, $p < 0.001$ (Fisher's Exact Test, 2-tailed). Accordingly, the hypothesis that social environmental factors increase the likelihood of violations was supported.

6. Discussion

The results of this study indicate that the three hypotheses under examination were supported, demonstrating that some error types are more associated with certain local conditions or organisational factors than other error types. Task demand factors were more often associated with skill-based errors than other error types, implying that factors such as distractions and high workload affect processing primarily at an automatic level of control in the context of rail incidents and accidents. This result provides support for Reason's (1990, 2008) proposition that these errors can be often imputed to failures of attention.

Confirmation of the relationship between task factors – such as high workload and distraction – and skill levels, as well as the relationship between knowledge and training factors and mistakes, is consistent with models of information processing. Specifically, these findings highlight that skill-based errors and mistakes represent distinct shortcomings. This finding aligns with the results of previous studies that have explored associations between errors and contributing factors in non-rail incidents and accidents (Hobbs and Kanki, 2008; Hobbs and Williamson, 2003). For example, through their logistic regression analysis, Hobbs and Williamson (2003) found a statistically significant association between pressure (one aspect of task demands) and memory lapses (a type of skill-based error). Further, they found knowledge-based errors were significantly linked to deficiencies in training.

The significant association between violations and social environmental factors provides support for the applicability of the theory of planned behaviour to an organisational context in the rail industry. That is, initiatives to shift the social norms of an organisation could translate to a reduction of violations. This association similarly provides support for Lawton's (1998) framework for understanding violations; however, the present study focused only on limited concepts within these theories and could not provide a robust test of these associations. Again, this finding is also in line with results of previous research, where a correspondence analysis indicated associations between violations and social norms factors (Hobbs and Kanki, 2008).

The findings in terms of associations and their similarities with research conducted in other industries provide confirmation of the proposition by Hobbs and Williamson (2003) that associations between factors are more easily generalisable. At a practical level, these findings provide guidance for organisations wanting to minimise or preclude these errors and violations. If an organisation was particularly concerned about high levels of skill-based errors, then measures could be introduced to reduce workload by employing more staff. Similarly, distractions in the workplace, such as unnecessary communications during periods of high workload, should be curbed.

In contrast, training would be a key area for improvement if mistakes were found to be prevalent. Training may need to cover more concepts or provide more detail on certain aspects. Alternatively, employees may need further supervised experience conducting non-routine tasks.

Finally, when violations are an organisational concern, efforts should be directed to improving compliance with rules and procedures through strengthening the safety culture of the organisation.

The finding that some local conditions and organisational factors were not associated with the other error types is important, reinforcing the need to understand the type of error that has occurred before deciding on remedial action. A common recommendation arising from investigations (particularly those that have not applied a systemic approach) is for the purported perpetrator to undergo re-training in the task they were performing when the incident occurred. Obviously, training would not be a useful course of action where a skill-based error or a violation has occurred. Instead, a more targeted approach to accident analysis and the recommendations arising from investigations is required.

The reasons for the large number of individual or team actions classified in the present study as unknown or other require some exploration. The unknown category was utilised where there was insufficient information available within the investigation report to determine whether the action was a violation or an error. The 'other' category was used for situations in which it was clear that the action was an error, but there was no information to assist in determining at what level of processing the error occurred. The lack of information about errors within these investigation reports may represent a commitment to the systemic investigation philosophy in terms of minimising the analysis of the actions of the individuals and focussing more on identifying and changing the systemic conditions which lead to the accident. However, this strict approach may be misguided as, if the true nature of the individual's action is not determined, it is difficult to fully analyse why the behaviour occurred and implement strategies to avoid it occurring again.

Alternatively, information regarding the cognitive processes behind action may not be available to the investigator, for example where the person involved in the incident or accident was unable to be interviewed. However, gathering this information is important to enable learning from past events and as such the collection of more detailed error information during rail investigations is recommended. This may require investigators to receive more in-depth training in human factors and human performance, or the use of experts in these fields where the actions of individuals are implicated in an event. A need for more detailed information about human error in investigation reports has been identified previously (Rail Safety and Standards Board, 2009).

Although 169 individual or team actions were documented, only half had one or more local conditions or organisational factors associated with them. This may be due to the investigation focusing on a different chain of causes, usually involving another error, or because of a lack of clarity in the investigation reports with evidence missing that could provide the grounds for linking an organisational factor to an error. Alternatively, it is possible that these errors, or a subset of them, did not have any other factors contributing to them, being purely associated with an individual's cognitive functioning or the impact of personal factors such as emotion. However, it is still necessary for an organisation to put defences in place to prevent these errors from leading to accidents. The concept of the inevitability of error is well accepted, but this does not mean that it is acceptable for accidents to occur due to these errors; systems need to be error tolerant (Reason, 2008).

In addition to issues such as the quality of investigation reports in documenting all contributing factors, and providing evidence to enable linkages between factors, other limitations of these data need to be considered. Firstly, investigations follow different methodologies, which affect what aspects of an occurrence receive focus and to what extent systemic issues are identified (Hollnagel, 2008; Tvaryanas et al., 2006). Further, the aspects considered, and the way in which the evidence is interpreted, will be affected by the investigator's background and prior experience. Thus, there may be factors that are contributing to these accidents that were either overlooked or over-represented in accident reports, depending on methodologies used and the training and experience of investigators.

A related methodological issue is the subjective nature of the coding process. A sequence of complex decisions must be reached during coding. There was considerable variation in terms of which factors were initially identified by the individual coders as contributing factors for coding. This issue has been documented in previous research where it has been noted that interpretations of rail investigation reports varied considerably amongst raters (Baysari et al., 2008). Inter-rater reliability calculations performed on the initial coding where the coders had selected the same contributing factor ranged from .47 to .88 which, according to Landis and Koch (1977), represent moderate to almost perfect agreement. Any discrepancies in the original coding did not affect the results of the present study as two experienced coders were used to counteract this subjectivity, and the potential for error in coding, by coming to consensus on the final data set. Future studies of this nature should consider utilising a similar methodology and future research could analyse the decision-making processes for different coders to explore how attribution of casual factors is determined.

The utility of the CFF as a structured tool for collating accident data for analysis has been demonstrated in the present study. Future studies investigating contributing factors to rail accidents could consider using this framework as a basis.

A final note is necessary to acknowledge that the causal linkages involved in system accidents are complex and often combinations of factors at different levels of the system set up the conditions for human failure, be it error or violation. Nonetheless, the present study found statistically significant associations between certain factors which could provide a basis for further exploration.

7. Conclusion

Understanding the reasons for past accidents occurring can provide vital information about deficiencies which could lead to future accidents. The results of this study have provided information about what factors may influence individuals to make certain types of errors or commit violations. These findings are consistent with psychological theory and previous research, suggesting that they may be applicable across industries and contexts. Further, the present study has explored the error types and local conditions and organisational factors that contributed to a sample of Australia rail incidents and accidents. These findings may have practical significance for the rail industry.

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