A RETROSPECTIVE ANALYSIS OF WORK-RELATED DEATHS IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

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Accident investigations are a well recognised and accepted method used to improve health and safety, providing an important link between the lessons of past incidents and safer and healthier operations in the future. In Australia, The National Coronial Information System (NCIS) is a national internet-based data storage and retrieval system for Australian coronial cases. Information about every death investigated by an Australian coroner since July 2000 (January 2001 for Queensland) is stored within the system, providing a valuable source of data for OHS researchers. A retrospective analysis of 'construction work-related' deaths recorded in the NCIS is presented. Applying an accident causation model developed by Loughborough University to the data, causes of death in the Australian construction industry are identified. However, in many instances, the data do not permit the identification of causes beyond the immediate accident circumstances. Limitations inherent in the data and recommendations for systematic collection of data based upon systemic models of accident causation are made.

Keywords: incident causation, national coronial information system, workplace death.

INTRODUCTION

The Australian construction industry accounts for 9% of the Australian workforce but, in 2008–09, accounted for 11% of all serious workers' compensation claims, equating to 40 workers per day requiring one or more week off work due to injury or illness. In 2008-09 construction recorded more fatalities than any other industry and the fatality rate (5.9 per 100,000 employees) was more than twice the rate for all industries (SafeWork Australia, 2011). National compensation-based statistics relating to work-related injury and death do not generally permit detailed analysis of causes beyond the identification of the mechanism (e.g., 'struck by moving object, fall from height etc.) and agency of injury (e.g. mobile plant or transport). In order to guide prevention efforts, there is a need to better understand the causes of workplace injuries and deaths.

AIM

The aim of this paper is to explore the causes of work-related deaths occurring in the Australian construction industry. Drawing on data recorded in the National Coronial Information System and a systemic model of incident causation is used to identify causes of work-related deaths. Using an incident causation model developed by

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researchers at Loughborough University (HSE, 2003), the causal analysis identifies immediate causes of events leading to work-related deaths, as well as more distal shaping factors and originating influences.

INCIDENT CAUSATION

Efforts to prevent occupational injury and illness are likely to be shaped by assumptions made about how injuries and illnesses occur. Consequently, incident causation models are important because the choice of theoretical accident causation model affects the method of accident investigation and the subsequent findings of an investigation, a principle known as 'What-You-Look-For-Is-What-You-Find' (Lundberg *et al.*, 2009). Understanding how incidents occur is essential if a distinction is to be made between events that are relevant and those that can be ignored (Swuste, 2008).

Different models of injury/incident causation emphasise different aspects and are likely to give rise to different recommendations for prevention. Hopkins (1995) identifies two broad sets of assumptions inherent in incident causation, which he terms blaming the victim and blaming the system. The first of these approaches explains occupational injury and illness in terms of characteristics of workers themselves that make them particularly susceptible. Katsakiori *et al.* (2009) classify accident models into three groups as follows:

1. sequential accident models, which describe an accident as a sequence of events in a specific order;

2. human information processing models, which describe accidents in terms of human behaviour and actions; and

3. systemic accident models, which include organizational and management factors and describe the performance of the whole system.

Sequential models are simple linear 'cause-effect' models that describe an incident as a sequence of events that occurred in a specific order, such as the 'domino model' (Heinrich, 1959). An injury was seen as the logical conclusion of a sequence of events that commenced with a person's ancestry and social environment and culminated with a loss-producing incident. Heinrich's model may be criticised for focusing too much attention on the immediate circumstances surrounding incidents, when it is now recognised that unsafe acts and conditions have systemic and organisational causes. Also, Hopkins (1995) suggests it is misguided to attribute incidents to either an unsafe act or an unsafe condition because most incidents are the result of a complex interaction of multiple causes.

Systemic causation models highlight organizational and cultural factors in creating the conditions in which a precipitating event can result in a major incident. James Reason's 'Swiss cheese' model is the most widely cited model of this type. According to Reason (1990), incidents are caused by a complex interaction of latent and active failures. Active failures are immediate observable causes, similar to Heinrich's unsafe acts or conditions. These can be easily identified. However, latent failures may also be present in work systems. In a sense these are 'accidents waiting to happen' and can include poor design, low levels of training, a mismatch between levels of competence and responsibility and other systemic deficiencies. Over time, work systems build up defences against these latent failures.

However, in local workplaces, latent conditions combine with natural human tendencies and result in human errors or violations. These are unsafe acts committed at the human-system interface. James Reason suggests that many unsafe acts occur, but very few of them result in losses because systems have in-built defences, likened to layers of Swiss cheese. But, like Swiss cheese, these barriers have holes in them which vary in size over time. Should a situation arise in which the holes 'line up', the system's defences fail and errors result in organizational accidents.

Lundberg *et al.* (2009) reviewed the accident investigation manuals of eight Swedish organizations to identify the scope of investigations and the theoretical models which ether explicitly or implicitly underpinned the investigation manuals. They report that all manuals used systemic incident models, which identified active as well as latent factors. Systemic models of incident causation permit an analysis of causal factors that are chronologically, geographically or organizationally removed from the worksite. Thus, the focus is not solely on the immediate circumstances surrounding the incident. In the construction context, this means that the cause of incidents may traced back to systemic failures in the way that construction projects are procured, organized and managed (Suraji *et al.*, 2001; Manu, *et al.*, 2010).

A report prepared by Loughborough University and UMIST on behalf of the UK's Health and Safety Executive sought investigated the causes of 100 (relatively minor) construction incidents. The research team used the information obtained from people involved in selected incidents, including the victims and their supervisors, to describe the processes of incident causation in construction (HSE, 2003). The resulting model of incident causation identified originating influences affecting incidents in construction as including client requirements, features of the economic climate, the prevailing level of construction education, design of the permanent works, project management issues, construction processes and the prevailing safety culture and risk management approach. For example, the analysis of the 100 incidents revealed that more than half could have been prevented with alternative design solutions. Deficiencies in the risk management system were also apparent in almost all of the 100 incidents studied, which represents a significant management failure. Project management failures were also commonly reported, most of which involved inadequate attention to coordinating the work of different trades and manage subcontractors to ensure that workers on site had the requisite skills to perform the work safely.

The next level of contributing causes identified in the HSE model is termed "Shaping factors" which include issues, such as the level of supervision provided, site constraints, housekeeping and the state of workers' health and fatigue. Poor communication within work teams was also identified as an important shaping factor.

The most immediate circumstances in the HSE incident causation model are the suitability, usability and condition of tools and materials, the behaviour, motivation and capabilities of individual workers and features of the physical site environment, such as layout, lighting and weather conditions. While it is important to identify these immediate circumstances, the model acknowledges that construction incidents occur as a result of a complex process, involving proximal, as well as distal causes, many of which originate "upstream" of the construction site.

The model developed by researchers from Loughborough University (HSE, 2003) formed the theoretical underpinning of the analysis presented in this paper.

RESEARCH METHODS

The National Coronial Information System (NCIS) is a national internet database that allows the storage and retrieval of every death investigated by an Australian coroner since July 2000, (January 2001 for Queensland). The primary role of the database is to assist coroners in their role as death investigators, by providing them with the ability to review previous coronial cases that may be similar in nature to current investigations and enhancing their ability to identify and address recurrent hazards within the community. The objectives of coronial investigations are to:

- investigate 'sudden and unexpected', or 'violent and unnatural' deaths;
- to determine what caused such deaths; and
- where appropriate, indicate ways in which similar deaths may be prevented in future.

The NCIS is intended to support the attainment of these objectives.

Although not originally established for the purpose of injury surveillance, the information captured in the NCIS has the potential to support analysis and research that, in turn, can help government agencies to develop community strategies for the prevention of injury and disease. In the present analysis, the NCIS was identified as a valuable source of information concerning the causes of work-related fatalities in the construction industry due to the richness and availability of information stored. Detailed information on fatalities such as time of the incident, age and occupation of the deceased and activities that led to the incident are contained within incident reports captured by the database. This allowed a more detailed analysis of the causes of fatal injuries than would otherwise not be available through an analysis of national compensation-based statistics.

CASE IDENTIFICATION

To identify relevant cases for analysis, the NCIS database was searched using the following search strategy. Three different fields were used to identify suitable cases for analysis. These were (i) the case status; (ii) a field indicating work-relatedness; and (iii) the case jurisdiction. The case status used to identify cases that were 'closed.' This was necessary to ensure that investigations identified for conclusion had all been completed. Detailed information about current cases is not available from the system. The 'work-relatedness' field was used to identify cases of death that were deemed (by the relevant State and Territory coroners' offices) to be work-related, i.e, the death occurred as a result of an incident or exposure occurring at or arising from paid work. Finally, the 'case jurisdiction' field was used to classify cases according to the State or Territory in which the death was investigated.

Next, a series of eligibility criteria were applied to the cases that were identified. For each case to be eligible for inclusion in the analysis, certain criteria must be met. First the case must have involved a construction industry worker. This was ascertained by examining the 'occupation' field and supporting information contained with attached investigative documents. Cases were excluded, for example if the deceased was a tradesperson engaged in a workplace other than a construction site, for example a mine site. Similarly, cases that identified the deceased as being of a construction related occupation but in which the death occurred as a result of an activity outside of work, such as being involved in a car accident to or from work, were also excluded from the analysis.

A total of 258 cases occurring between 2000 and 2010 were identified using these search terms and criteria. These cases were included in the final analysis. Table 1 shows a breakdown of the cases included in the analysis by State/Territory in which the investigation took place and year. The highest number of work-related construction fatalities were found to occur in New South Wales (29%) and Queensland (28%), while the Northern Territory and the Australian Capital Territory accounted for the smallest numbers of cases in the analysis (1.9% each).

Table 1: Cases included in the analysis by year and State/Territory

Year	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2000	0	4	0	0	2	0	2	2
2001	1	15	1	19	6	1	5	3
2002	1	9	0	6	2	2	4	7
2003	1	10	0	6	1	2	6	5
2004	0	7	2	6	1	1	10	5
2005	0	9	0	7	3	2	3	5
2006	1	9	0	9	2	0	2	1
2007	0	6	2	11	1	0	4	3
2008	0	6	0	7	1	0	1	2
2009	0	0	0	2	1	1	0	1
Total	5	75	5	73	20	9	37	34

Next, thematic content analysis of coroners' findings was undertaken to code the causes of incidents that led to the deaths. Data were coded according to the categories of Immediate Causes, Shaping Factors and Originating Influences identified in the HSE incident causation model (HSE, 2003). The analysis was a deductive process commencing with an identification of the immediate circumstances of the incident, i.e, the tools and materials involved, workers' behaviour and site conditions and environment. Working back from these immediate causes, shaping factors and then originating influences were identified wherever possible from the coroner's reports.

RESULTS

The mean age of the workers involved in a work-related construction fatality was 43 years, ranging from 16 through to 79 years of age. The majority of decedents were male, representing 98% all deaths, while females made up the remaining 2% of decedents (n=4). Decedents represented 45 different construction occupations. The occupations most frequently involved in the work-related construction deaths in the analysis were electricians and construction labourers, each accounting for 42 decedents (22% of cases). Other trades prevalently involved in the incidents in the analysis were truck drivers (N=23, 12%) and plant operators, i.e. bulldozer drivers, backhoe operators, etc (N=23, 12%). Most of the fatal incidents in the analysis occurred between 7am and 5pm, with two peaks in incidence occurrence recorded between 9 and 10am and 3 and 4pm. Interestingly the first of the two peaks coincide with a common construction practice of workers stopping for a morning 'smoko' break, while the second corresponds to preparing for the end of the working day. This suggests that fatigue may be a possible causal factor related to these peaks in incident occurrence.

Figure 1 shows the results of the analysis by the level of causes that were identified. It is noteworthy that in 66 cases (26%), no clear causes could be identified from the documents available in the NCIS. These cases were excluded from further analysis. Of

the remaining 192 cases causes classified as 'immediate causes' could be identified. Of the 192 cases for which immediate causes could be identified, causes classified as 'shaping factors' could be identified in 121 (63%) of cases. In a further 87 (45%) of cases, it was possible to trace these shaping factors back to causes classified as 'originating influences' according to the HSE model. This preliminary analysis suggests that many coronial investigations may focus predominantly on immediate circumstances surrounding an incident and may not identify the extent to which these immediate factors arise as a result of shaping factors or originating influences that are known to contribute to the causation of safety incidents in the construction industry.

Figure 1: Distribution of incidents for which immediate circumstances, shaping factors and originating influences could be identified
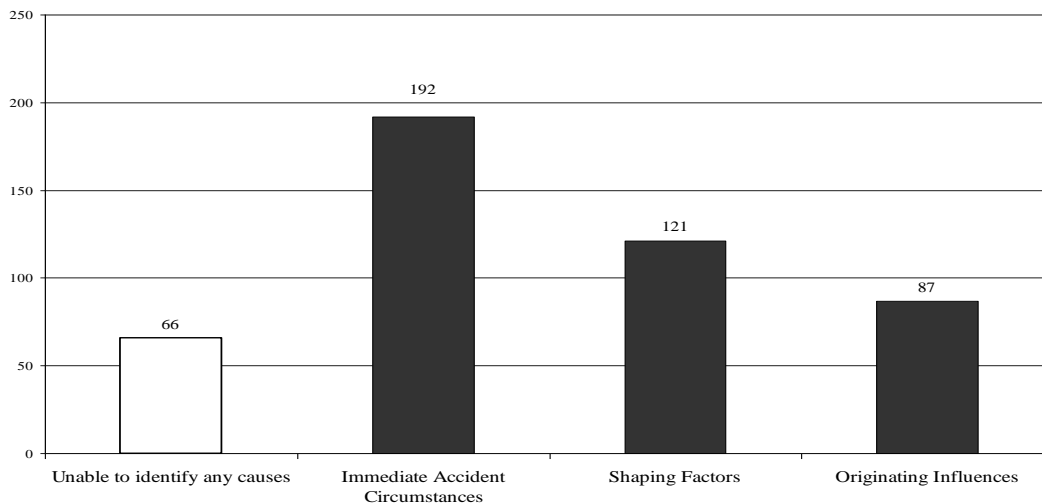

Table 2 provides a breakdown of the frequency with which each of the immediate circumstance causes, shaping factors and originating influences was identified in the coronial findings. Workers' own actions were identified in 128 or 66% of the cases in which immediate circumstance causes were identified. Also frequently identified among the immediate circumstance causes were aspects of the site layout (44% of cases), equipment suitability (24% of cases) and local hazards (11% of cases). The most commonly identified shaping factors involved in the coronial findings were related to the design of the workplace (40% of cases), workers' knowledge and/or skills (37% of cases), site constraints (36% of cases) and supervision (30% of cases). A failing in risk management was the most frequently identified originating influence in the coroners' findings accounting for 43 (or 49%) of all cases in which originating influences were identified. Other commonly identified originating influences were unsafe construction processes (22% of cases), safety culture (21% of cases), construction education (15% of cases) and permanent works design (14% of cases).

In many instances the NCIS data is sufficiently 'rich' that multiple causes can be identified relating to a particular incident. The incident causation model provides a useful framework for the analysis of causes at ranging from those relating to the immediate circumstances of the incident to distal causes that may be chronologically, organizationally or geographically separated from the incident itself. The potential for the data to be used to identify multiple incident causes is best illustrated through the use of an example case analysis presented in the next section.

Table 2: Immediate causes, shaping factors and originating influences involved in work-related deaths

Immediate Accident Circumstances	No. identifed.	Shaping Factors	No. identifed.	Originating Influences	No. identifed.
Action	128	Attitudes/motivations	18	Permanent works design	12
Behaviour	12	Knowledge/skills	45	Project managemt.	7
Capabilities	10	Supervision	36	Construction processes	19
Communications	18	Health/fatigue	2	Safety culture	18
				Risk management	43
Layout	85	Site constraints	44	Client requirements	3
Lighting/noise	3	Work scheduling	5	Economic climate	2
Hot/cold/wet	1	Housekeeping	4	Construction education	13
Local hazards	22				
		Design	48		
Equipment suitability	47	Specification	2		
Equipment usability	5	Supply/availability	1		
Equipment condition	12				
Material suitability	6				
Material usability	0				
Material condition	1				

Case example

The deceased was in the final year of completing his apprenticeship as a plumber and gasfitter. This meant that he was unlicensed and was required to be under the supervision of a qualified plumber. The day prior to the incident the deceased's supervisor requested the he to attend a caravan park where a mobile home, permanently housed there, to fit with a new gas water heater. Later in the day, after works had commenced, the deceased realised that he did not have the equipment he required to complete the job. The deceased returned the following day and began work in hole that had been dug the previous day and began work on connecting the new gas line to the town mains gas line. It was while undertaking this work that the deceased damaged the mains gas supply and was overcome by gas. Efforts to revive him failed. During the course of the investigation it was identified that the owner of the mobile house had not advised the caravan park proprietor of any works. Further, the proprietor was unaware of the presence of any tradesman on site despite having security/access restriction at the park entrance and a 'sign-in' process in place. Details of the incident identified immediate circumstances, shaping factors and originating influences. Figure 2 provides a breakdown of the causes identified for this incident at each level of the model.

The NCIS database also permits the analysis of relationships between causal factors at each 'level' in the HSE model. Thus, it is possible to explore the linkages between originating factors and the shaping factors and immediate circumstance causes that may 'flow' from them. Analysis of the NCIS data is ongoing to identify in detail the causal 'pathways' leading up to work-related deaths in the construction industry. An example of this analysis is shown in Figure 3, which shows the relationship between shaping factors and immediate circumstances for all deaths in the sample in which 'design of the permanent building/structure' was identified as an originating influence, i.e, in all case for which permanent design was identified as a distal cause of the incident.

Figure 2: Analysis of causes relating to the 'gasfitter' fatality case example

Shaping Factors

- *Client requirements* - did not control access onto the site
- *Project management* - clients failed to manage their site effectively
- *Permanent works design* - little documentation and no 'owner of the gas system' as required by AS4645-2005
- *Risk Management* - risk processes were not followed
- *Construction education* – alerting plumbing industry of the dangers associated with gas mains and type of gas involved

Originating Factors

- *Supervision*, or lack of;
- insufficient *Knowledge/Skills* to carry out the work ; and
- *Attitudes/motivation* of the supervisor given that he was fully aware of the capabilities of the deceased and displayed surprise when he found out that the project was taking so long.

Immediate Accident Circumstances

- *Equipment Suitability* (not using the correct equipment to allow for safe connection to the gas mains
- *Capabilities* – the deceased was not trained in the work being undertaken and failed to recognise what equipment was required to carry out the work safely;
- *Layout* – a hole had been dug around the mains lines pipe and access to these pipes was by way of the deceased laying on his stomach on the ground with his head, arms and the top part of his body into the hole; and
- *Actions* – was not wearing any PPE and did not use the gas detection metre, despite having it
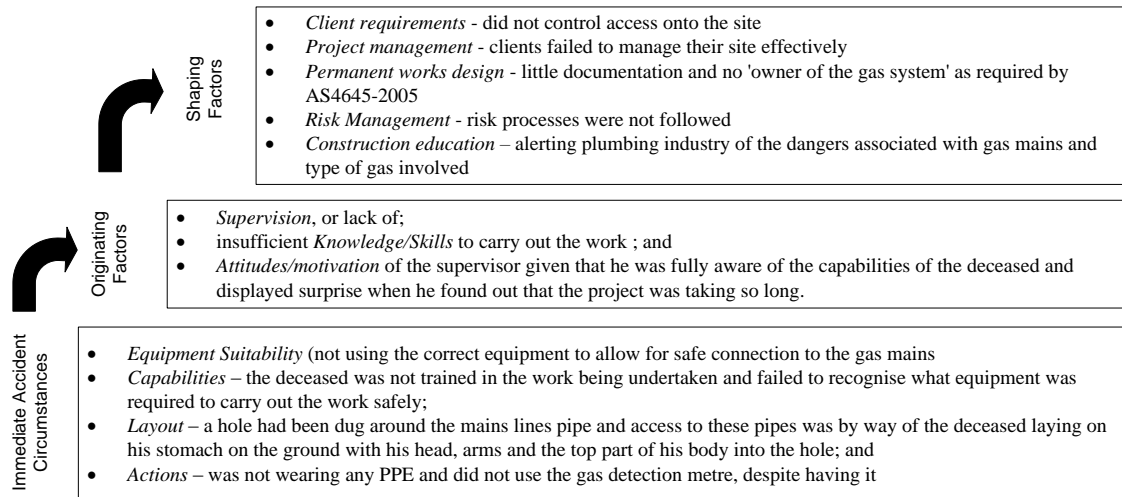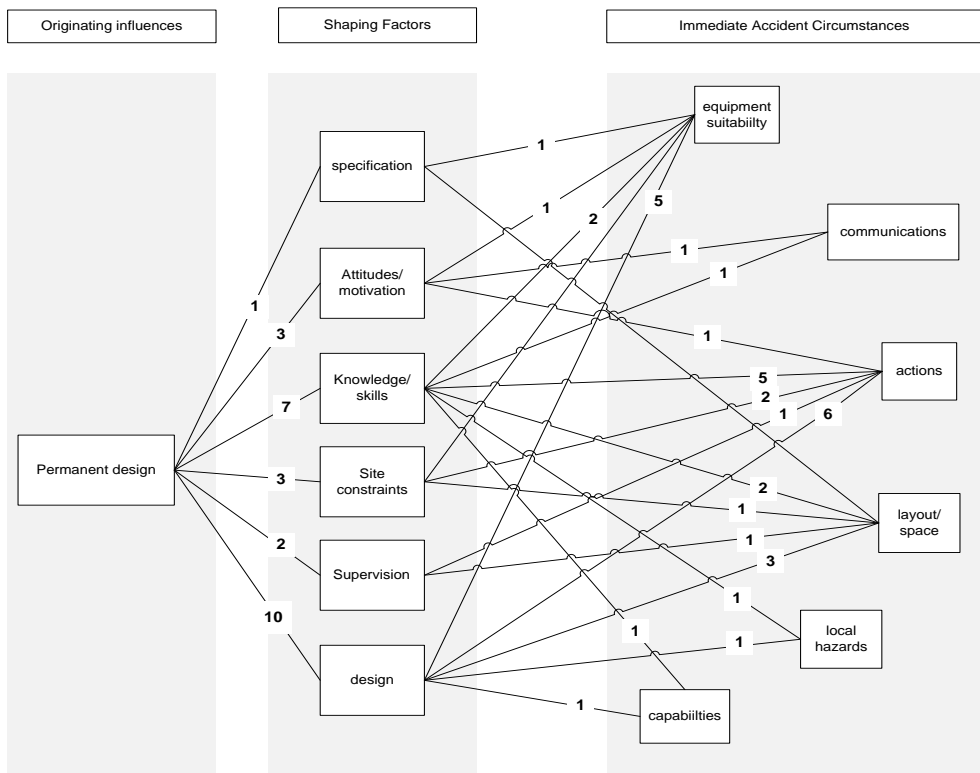
Figure 3: Relationship between shaping factors and immediate causes traced back to the originating factor of 'permanent works design.

Of the 12 cases for which the permanent works design was identified as an originating influence, ten (83%) also identified design as a shaping factor. Of the cases in which the design was identified as a shaping factor six workers' actions were identified as immediate circumstances flowing from the design of plant or structures. Design was also linked to five instances of equipment unsuitability, one local hazard issue and one issue relating to workers' capability. The second most prominent shaping factor identified in cases for which the design of the permanent building/structure was identified as an originating influence was knowledge/skills (n=7, 58%). The shaping factor of knowledge/skills was linked to five unsafe worker actions, two issues relating to equipment suitability, two issues relating to layout/space, one communication issue, one capability issue and one example of a local hazard.

Consistent with the view that most incidents are the result of a complex interaction of multiple causes, each fatality case in the analysis could have an infinite number of causal factors assigned to it, at each level. Thus, a single incident could have multiple originating factors which were each linked to multiple shaping factors, which could each be linked to multiple immediate circumstances in this analysis.

The analysis of causal pathways using this approach is ongoing and it is envisaged that, the data can be ultimately used to identify the most prevalent pathways (causal links) in the occurrence of work-related deaths in the construction industry. This will provide a more helpful basis for the development of prevention strategies than more simple breakdowns of incidents by mechanism of injury or agency of injury currently available.

DISCUSSION AND CONCLUSION

The results of this preliminary analysis of data from the NCIS database shows that the systemic incident causation model developed on behalf of the HSE by researchers from Loughborough University is potentially useful in the causal analysis of work-related fatal incidents in the construction industry. The cases identified through the NCIS database and subjected to the analysis indicated causal factors at each level in the model, e.g. originating influences, shaping factors and immediate circumstances. This is consistent with previous research linking "upstream" originating influences, such as permanent works design and client management activities, in causal pathways via intermediate shaping factors to the immediate circumstances surrounding incidents. While the model proved useful, some limitations in its use were experienced. A full discussion of these limitations is beyond the scope of this paper. However, two issues encountered were: (i) that classification of factors was open to interpretation, which could lead to the identification of different causal pathways; and (ii) that not all incident scenarios were adequately represented by the 'hierarchical' sequence of causal factors implied by the HSE model.

Many reports in the NCIS identify workers' own actions as the immediate cause of the incident. While unsafe actions on the part of decedents and others are undoubtedly an important causal factor in incident occurrence, systemic models of incident causation seek to "explain" workers' behaviour in relation to features of the entire system of work, including organizational and management factors. There is arguably a need to understand workers' unsafe behaviour in context in order to properly address the 'root' causes of behavioural safety issues (Bellamy *et al.* 1997). The analytical approach applied to the NCIS database may help to achieve this.

It is noteworthy that in the coronial findings, shaping factors and originating influences were identified in fewer cases than immediate causes. It is possible that, in the case of some incidents, immediate circumstances are not traced back to their "root" causes. It is possible that the use of a theoretical systemic causation model, such as that developed by the HSE, to inform investigations may yield more comprehensive data relating to incident causation that can then be used to drive prevention strategies. The preliminary analysis of causal pathways also suggests that the 'narratives' contained in the NCIS database can be used in the analysis and management of systemic risks in construction (c.f., Bellamy *et al.* 2008).

Finally, there is evidence that different mechanisms of causation apply to fatal and non-fatal incidents (Saloniemi and Oksanen 1998). It is important to test this

proposition in further research using richer data about the circumstances in which incidents occur.

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