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Abstract: Evidence indicates that injuries occur regularly during led outdoor activities. Despite calls for a systems approach to assessing and preventing injurious incidents, there is little evidence that systems failures play a causal role. This article presents an analysis of 1017 led outdoor activity injury and near miss incidents whereby a systems-based risk management framework was used to classify the contributing factors involved. The contributing factors were placed across six levels of the led outdoor activity 'system' as described by the framework. The analysis identified causal factors across all levels of the led outdoor activity system, providing evidence that a systems approach is applicable within the led outdoor activity injury context. In addition, issues associated with the current data collection framework that potentially limited the identification of contributing factors outside of the individuals, equipment, and environment involved were identified. In closing, the requirement for new and improved data systems to be underpinned by the systems philosophy and new models of led outdoor activity accident causation is discussed.

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Friday 21st December 2012

Dear Karl,

Please find attached the following submission for consideration for publication in the Accident Analysis and Prevention journal:

Injury causation in the great outdoors: a systems analysis of led outdoor activity injury incidents

If there are any problems with the submission please do not hesitate to contact me using the details provided. I look forward to hearing from you in the near future regarding the outcome of the review.

Yours truly,

A/Prof Paul Salmon

Highlights

- Injuries are problematic in the led outdoor activity (LOA) domain;
- Little incident data or analyses are available in the LOA context;
- We present a systems analysis of LOA incident data from New Zealand;
- The analysis identified causal factors across all levels of the LOA system;
- The analysis shows that a systems approach is applicable in the LOA context.

Injury causation in the great outdoors: a systems analysis of led outdoor activity injury incidents

Abstract

Evidence indicates that injuries occur regularly during led outdoor activities. Despite calls for a systems approach to assessing and preventing injurious incidents, there is little evidence that systems failures play a causal role. This article presents an analysis of 1017 led outdoor activity injury and near miss incidents whereby a systems-based risk management framework was used to classify the contributing factors involved. The contributing factors were placed across six levels of the led outdoor activity 'system' as described by the framework. The analysis identified causal factors across all levels of the led outdoor activity system, providing evidence that a systems approach is applicable within the led outdoor activity injury context. In addition, issues associated with the current data collection framework that potentially limited the identification of contributing factors outside of the individuals, equipment, and environment involved were identified. In closing, the requirement for new and improved data systems to be underpinned by the systems philosophy and new models of led outdoor activity accident causation is discussed.

Keywords: *Human factors, Injury, Accident causation, Systems analysis*

Introduction

There is an acknowledged risk of both severe and frequent injury associated with active pursuits, especially those participated in for sport, active recreation or leisure (e.g. Finch et al, 2007; Flores et al, 2008; Gabbe et al, 2005). One important educational form of active recreation is led outdoor activities, which are defined as facilitated or instructed activities within outdoor education and recreation settings that have a learning goal associated with them (Salmon et al, 2010). Examples include activities such as school and scout camping, hiking, harness sports, marine aquatic sports and wheel sports. Although little accident and injury data is available, evidence from a range of sources suggests that injuries are common place during led outdoor activities. These sources include longitudinal studies (e.g. Barst, Bialeschki, & Comstock, 2008; Hill, 2011), accident investigations (e.g. Brookes et al, 2009), and the academic literature (Brookes, 2011). While a lack of exposure data means the exact injury rates are unknown, recent high profile fatal incidents in Australia and New Zealand further highlight the industry's need to better understand the causal factors involved and to develop appropriate injury and accident prevention strategies. These include the drowning of a 12 year old student whilst on a college camp and the Mangatepopo Gorge walking incident in which six students and their teacher drowned (Brookes et al, 2009).

Accident analysis is an accepted approach for identifying and understanding the causal factors involved in safety compromising accidents and incidents, and for informing the development of strategies and countermeasures designed to improve safety (Cassano-Piche et al, 2009). Recent research has questioned the current approach taken to understanding and preventing injury incidents in the led outdoor activity domain. Salmon et al (2010; 2012), for example, argue that an approach underpinned by contemporary systems theory-based models of accident causation, widely used in safety critical domains such as aviation, process control, and mining, is required but has not yet been adopted. Although recent incident investigations suggest that catastrophic multiple fatality led outdoor activity incidents are the result of multiple failures across the overall led outdoor activity system (e.g. Brookes et al, 2009), there is little evidence to demonstrate that this is the case for the everyday injury incidents that occur (e.g. falls, sprains and strains). The aim of the study described in this article was to test the notion that the injury causing incidents that occur during led outdoor activities involve failures across the led outdoor activity system, and that individual (e.g. instructor and participant) and environmental factors also contribute. In addition, following other contemporary accident analysis studies in other domains (e.g. Lenné et al, 2012; Lie, Harris and Yu, 2008); a secondary aim was to investigate the relationship between causal factors across the led outdoor activity system. The study involved the use of a popular systems-based risk management framework and associated accident analysis method (Rasmussen, 1997) to classify the factors identified from an analysis of 1017 led outdoor activity incidents derived from the New Zealand Outdoor Education/Recreation National Incident Database.

The systems approach

The systems approach to accident causation centres on the notion that safety, and indeed accidents, are emergent properties arising from non-linear interactions between multiple components across complex sociotechnical systems (e.g. Leveson, 2004). Various models of accident causation underpinned by this philosophy are discussed in the literature (e.g. Leveson, 2004; Perrow, 1984; Rasmussen, 1997; Reason, 1990). Based on a review and comparison of models, Salmon et al (2010) concluded that Rasmussen's (1997) risk management framework and accompanying Accimap accident analysis framework are suited for application to the led outdoor activity context. Rasmussen's risk management framework (see Figure 1) argues that work systems comprise various levels (e.g. government, regulators, company, company management, staff, and work), each of which are co-responsible for production and safety. With regard to accident causation, the framework argues that decisions and actions at all levels of the system interact with one another to shape system performance: safety and accidents are thus shaped by the decisions of all actors, not just the front line workers in isolation, and accidents are caused by multiple contributing factors, not just one bad decision or action. The model also argues that ‘vertical integration’ is required for safe and efficient performance. That is, decisions made at higher governmental, regulatory, and managerial levels of the system should propagate down and be reflected in the decisions and actions occurring at the lower levels. Conversely, information at the lower levels regarding the system’s status needs to transfer up the hierarchy to inform the decisions and actions occurring at the higher levels (Cassano-Piche et al, 2009).

****INSERT FIGURE 1 HERE****

To support use of the framework in accident analysis studies, Rasmussen (1997) outlined the Accimap framework for analysing accidents. Accimap (Rasmussen, 1997; Svedung & Rasmussen, 2002) is used to graphically depict the decisions, actions, and conditions that interacted with each another to produce the accident in question. Accimap typically structures these contributing factors across six organisational levels: government policy and budgeting; regulatory bodies and associations; local area government planning & budgeting; technical and operational management; physical processes and actor activities; and equipment and surroundings. Factors at each of the levels are identified and linked between and across levels based on cause-effect relations. Based on a comparison of three popular accident analysis methods, Salmon et al (2012) concluded that the Accimap framework was the most suitable for analysing multiple led outdoor activity injury and near miss incidents.

In testing the systems approach in the led outdoor activity context, three key tenets of Rasmussen’s risk management framework were investigated through the present study. First, that the incidents would involve decisions and actions made by actors across the led outdoor activity system, not just instructor and participant decisions and actions alone. Second, that the incidents would have multiple contributing factors, not just a single erroneous decision or action. Third, and finally, the incidents would have contributing factors across multiple levels of the led outdoor activity system, not just from one level alone. The presence of these three tenets in the data set would provide confirmation that the everyday led outdoor activity minor injury incidents require a systems approach for both analysis and prevention efforts.

The systems approach in the great outdoors

To enable the Accimap framework to be used in the analysis of led outdoor activity incidents, the six systems levels typically used in Accimap analyses were modified to reflect the led outdoor activity domain. This led to the definition of the following six led outdoor activity system levels:

1. *Equipment and surroundings:* factors associated with the equipment used in support of the activity, the physical environment in which the activity was undertaken, and the ambient and meteorological conditions prior to or during the incident;
2. *Physical processes and instructor/participant:* activities undertaken 'at the sharp end' prior to, and during, the incident. It therefore describes the flow of events leading up to and during the incident in question. This includes decisions and actions made by instructors, participants. Etc., but may also include decisions and actions made by other actors, such as supervisors, emergency responders, members of the public, etc;
3. *Technical and operational management:* activities, decisions, actions, etc made by personnel at the supervisory and managerial levels of the organisation providing the activity involved in the incident. These factors typically occur prior to the incident itself but can also include decisions and actions made during, or in response to, the incident.
4. *Local area government, activity centre management planning and budgeting:* activities, decisions, actions etc made by personnel working in local government and at the senior

managerial levels of the activity centre involved (e.g. executive board level). These factors are related to higher level management, planning and budgeting activities and typically occur before the incident itself (this can even be years preceding the incident);

5. *Regulatory bodies and associations, schools and parents:* activities, decisions, actions etc made by personnel working for led outdoor activity regulatory bodies or associations and the schools involved. Decisions and actions made by the parents of the participants involved in the activity are also included at this level.
6. *Government policy and budgeting:* decisions, actions etc relating to the provision of led outdoor activities, such as those relating to funding and policy development

New Zealand National Incident Database study

The aim of this study was to analyse a series of led outdoor activity injury and near miss incidents using Rasmussen's risk management framework. Accordingly, factors identified from the incident data were classified, using the modified Accimap levels described above, in order to identify contributory factors from across the led outdoor activity system. The data was taken from the New Zealand Outdoor education/Recreation National Incident Database (OER NID). A description of the OER NID can be found at http://www.incidentreport.org.nz/. The database is used by commercial, educational, not for profit, or informal groups and individuals involved in outdoor activities. Full approval for the study was given by the New Zealand Mountain Safety Council who operate the NID on behalf of the Outdoor Sector. Although the authors of this article reside in Australia, there are few Australian databases that collect exhaustive data on led outdoor activity injury incidents. The OER NID was the only readily available database that contained sufficient data to support the present analysis and thus provided the most appropriate data set for the study.

Method

Data source

All data on led outdoor activities from the OER NID collected between 1 January 2007 and 31 December 2011 were included in the analyses (n = 1017). The data were provided to the researchers by the New Zealand Mountain Safety Council in an electronic spreadsheet in de-identified form (with names of all individuals and organisations removed). Prior to commencing the study, ethics approval was granted by the Monash University Human Ethics Committee. The data were organised across six core fields: causal instructor, causal participants, causal equipment, causal environment, incident description, and causal narrative. A summary of each field is presented in Table 1. The subsequent analysis focussed on the data within these fields.

****INSERT TABLE 1 HERE****

Data coding

Coding was conducted over four stages. First, the causal factors identified in the *Causal Instructor*, *Causal Participant*, *Causal Equipment* and *Causal Environment* multiple response fields were extracted for each case. Second, three researchers experienced in coding incident data independently identified causal factors from the *incident description* and *causal narrative* fields, and assigned descriptive codes to the text. Each factor had to be explicitly identified in the text and researchers were not permitted to draw any inferences from the reports. For example, from the Causal Narrative "A large group of kids moving along a road....maybe distracted by talking to each other and running around etc." the factors "large number of participants" and "distracted participants" were identified. Three cases were excluded from further analysis as causal factors were not identified. Third, one researcher collated all the factors identified from the data and ordered them into categories based on key themes. For example, "participant horseplay" "participant acting unsafely/being silly", "participant error" and "participant poor behaviour" were all assigned to the theme "participant unsafe acts". The aim was to reduce the overall number of factors identified in the data, while still retaining enough detail to generate meaningful injury prevention strategies. The categories were then reviewed by the two other researchers, and the few disagreements resolved through consensus discussion. Finally, the causal factors were placed across the six Accimap levels described above. For example, 'participant unsafe acts' was placed at the '*Physical processes and instructor/participant activities'* level.

Statistical analysis

In first phase of the analysis, analysis of incident characteristics and causal factors were performed using frequency counts. In second phase of the analysis, associations between each level of the modified Accimap framework with the one above were examined using odds ratios. Fisher's Exact Test was used to test for associations when odds ratios could not be calculated due to zero cell counts. The odds ratio is interpreted as follows: An odds ratio of 1 implies no association. If the odds ratio is greater than 1, and its 95% confidence interval does not include 1, then the result implies a positive association between the higher level and the lower level at the 5% significance level (i.e. the odds of the presence of a lower level factor is greater in cases where a higher level factor is present compared to when it is absent). If the odds ratio is less than 1, and its 95% confidence interval does not include 1, then the result implies a negative association between the higher level and lower level at the 5% significance level (i.e. the odds of the presence of a lower level factor is greater in cases where higher level factors are absent compared to when they are present). If the 95% confidence interval includes 1, then the association is not significant (Bigby, 2000; Bland & Altman, 2000).

Results

Incident characteristics

Across the 1014 incidents, there were 596 injuries (58.8%), 272 near misses (26.8%), 161 illnesses (15.9%) and 6 fatalities (0.6%). Nine incidents involved both an injury and an illness (0.01%). A near miss was defined as an incident where an adverse outcome did not occur, but the potential for injury was present. Common near miss incidents involved participant unsafe acts (e.g. participant jumping on bunk bed), violations of safety procedures (e.g. failing to clip a carabineer while climbing, racing another car while driving), and property damage (e.g. traffic accident).

Overall, 99 different activities were coded in the original data file. In order to aid comparisons across similar activity types, activities were grouped into 15 categories. Activities that could not be clearly categorised were coded as “miscellaneous”. The activity type most represented in the data was walking/running activities (24.9% of incidents), followed by boating activities (13.9% of incidents) and camping (12.7% of incidents). Table 2 shows the frequency and percent of incident outcomes by activity type. The activity type associated with the highest proportion of injuries was weapons (100% within weapons incidents), closely followed by skiing and boarding (91.3% within skiing and boarding incidents) and initiatives (91.1% within initiatives incidents). The activity type associated with the highest proportion of illnesses was camping activities (60.5% within camping incidents). The activity type associated with the highest proportion of near misses was ropes (55.8% within ropes incidents). The activity type associated with the highest number of fatalities was boating (2.8% within boating incidents).

****INSERT TABLE 2 HERE****

The number of participants (M = 17.94, SD = 29.59), qualified instructors (M = 1.68, SD = 2.07), parent/volunteer helpers (M = .76, SD = 2.10) and supervisors (M = 1.62, SD = 3.20) involved in each incident were coded in the original data file. Supervisors were defined as teachers or youth leaders.

Table 3 shows descriptive statistics for the number of participants, volunteer helpers and supervisors involved in each incident by activity type.

****INSERT TABLE 3 HERE****

Injury Characteristics

A total of 29 injury types were coded in the original data file. The injury types most represented in the data were sprains (23.15%), followed by lacerations and cuts (12.42%) and fractures (10.74%). Across all injuries, actual and potential severity ratings were low (M = 3.44; SD = 1.37, M = 4.77; SD = 1.66 respectively). According to the incident severity scale provided by the NZ NID (see Appendix A), these scores indicate that the actual severity of injuries was quite minor, with impacts limited to preventing immediate participation in the activity or programme. Potential severity is rated as medium; scores indicate that impacts may prevent participation in the activity or programme for a day or two. Injuries rated as the most severe were internal injuries, followed by snapped Achilles tendons. However, very few incidents involved these injuries (n = 3). Table 4 shows the frequency and percentage of injury types by mean actual and potential severity ratings.

****INSERT TABLE 4 HERE****

Causal factors across the led outdoor activity system

On average, 4.10 causal factors (SD = 2.33) were identified per incident. The factors most frequently involved in incidents were hazardous terrain (50.20% of all incidents), participant unsafe acts (29.78%) and instructor judgement errors (29.59%). In the following sections, the frequencies and percent of causal factors identified at each level of the led outdoor activity system are presented. A summary of the contributing factors across the led outdoor activity system levels is presented in Figure 2.

Government policy and budgeting

Few incidents (1.4%) involved factors at the government policy and budgeting level. Table 5 shows the presence of factors identified at this level. Failures associated with the Government department responsible for conservation were all incidents involving walking/running activities (4.8% of incidents within walking/running activities). The incident descriptions indicate the Department had been notified of these issues on prior occasions.

****INSERT TABLE 5 HERE****

Regulatory bodies and associations

Again, few incidents (2.0%) involved factors at the regulatory bodies and association's level. Table 6 shows the presence of factors identified at this level. Incidents involving factors at this level involved a wide range of activities types, including free time (2.8%), climbing (5.2%), walking/running (2%), camping (3.1%) and ropes (2.3%) (Percentages are within each activity type). The most frequently identified causal factor at this level was "parents fail to inform activity organisers of medical condition”. These incidents ranged from cases where the participant had an illness that should have precluded them from attending the activity (e.g. vomiting) to incidents where parents did not disclose long-term illness (e.g. epilepsy or asthma) to the activity provider.

****INSERT TABLE 6 HERE****

Local area government, activity centre management planning and budgeting, schools and parents

At the local area government planning level, 8.7% of incidents involved factors at the local area government planning and company management level. Table 7 shows the presence of factors identified at this level involved almost all activity types, including miscellaneous (3.4%), ball sports (9.1%), free time (9.7%), climbing (10.3%), walking running (6.3%), weapons (25%), camping (2.3%), boating (9.9%), caving (32%), swimming (6.3%), cycling (3%), ropes (11.6%), horse riding (25%) and initiatives (20%) (Percentages are within each activity type). The most frequently identified causal factor at this level was “poor/lack of risk management systems”. These incidents involved issues such as: risk assessments failing to identify a hazard that later caused an injury; not setting the boundaries for the activity away from a potential hazard; lack of systems to detect participants who were unfit for the activity; and control measures that failed to prevent an injury.

****INSERT TABLE 7 HERE****

Technical and operational management

Of the incidents analysed, 12.2% involved factors at the technical and operational management level. Table 8 shows the presence of factors identified at this level. Incidents involving factors at this level involved almost all activities types, including ball sports (9.1%), free time (6.9%), climbing (22.7%), walking running (10.3%), camping (2.3%), boating (14.2%), caving (35.3%), swimming (14.6%), cycling (27.3%), ropes (9.3%), skiing/boarding (4.3%) and initiatives (20%) and miscellaneous (3.4%), (Percentages are within each activity type). The most frequently identified causal factor at this level was "poor planning of activities". These incidents involved issues such as: general lack of planning for activity, lack of planning for weather conditions, unclear allocation of responsibilities between instructors and a lack of emergency plans.

****INSERT TABLE 8 HERE****

Physical processes and instructor/participant activities

91.4% of incidents involved factors at the physical processes and actor activities level. As many causal factors were identified at this level, Table 9 shows their frequency and percent according to higher level categories. Incidents involving factors at this level involved almost all activities types, including miscellaneous (93.1%), free time (91.7%), climbing (93.8%), walking running (88.1%), camping (86.8%), boating (91.5%), swimming (77.1%), cycling (97%), ropes (96.5%), and initiatives (97.8%) (Percentages are within each activity type). The most frequently identified causal factor at this level was "participant unsafe act". These incidents involved issues such as: participant "horsing around", slips and mistakes of action. Instructor judgement errors were also identified in a high number of incidents. However, often little detail was provided as to why a judgement error was attributed to the instructor.

****INSERT TABLE 9 HERE****

Equipment and surroundings

75.7% of incidents involved factors at the equipment and surroundings level. Table 10 shows the frequency and percent of factors identified at the environment and surroundings level. Incidents involving factors at this level involved all activities types: ball sports (72.7%), free time (63.9%), climbing (67%), walking running (88.9%), weapons (50%), camping (58.9%), boating (85.9%), caving (91.2%), swimming (97.9%), cycling (84.8%), ropes (66.3%), skiing/boarding (95.7%), horse riding (100%), initiatives (66.7%), motorbikes (100%) and miscellaneous (86.2%), (Percentages are within each activity type). The most frequently identified causal factor at this level was "hazardous terrain".

These incidents involved issues such as: uneven ground and slippery ground. However, often no more description was given than “terrain” or “hazardous terrain”.

****INSERT TABLE 10 HERE****

****INSERT FIGURE 2 HERE****

Associations between the levels in Rasmussen's Accimap Framework

In line with other recent accident analysis studies underpinned by systems-based methods (e.g. e.g. Lenné et al, 2012; Lie et al, 2008), a secondary aim this study was to determine whether the presence of factors at higher levels of the led outdoor activity system framework is associated with the presence of lower level factors. It is important to keep in mind that the absence of an association does not necessarily imply that the relationship between the levels is unimportant. For example, 85.7% of cases where a government level factor was identified also had a physical processes factor. However, the association is not significant because the number of cases that involve factors at the physical processes level far outweigh cases that involve factors at the government policy and budgeting level (91.4% of cases as opposed to 1.4% of cases).

Using the odds ratio approach, a significant positive association indicates that the odds of the presence of a lower level factor is greater in cases where a higher level factor is present compared to when it is absent, whereas a significant negative association indicates that the odds of the presence of a lower level factor is greater in cases where higher level factors are absent compared to when they are present. A summary of the positive associations found is presented in Figure 3.

****INSERT FIGURE 3 HERE****

As shown in Figure 3, there was a significant positive association between the regulatory bodies and associations level and the environment and surroundings level ($p < .01$). The odds of the presence of an environment and surroundings factor was significantly (3.22 times) larger in cases when a regulatory bodies factor was present than when it was absent ($p < .05$, CI = .12 - .76). A significant positive association was also found between the physical processes and instructor/participants level and environment and surroundings level ($p < .01$). The odds ratio could not be calculated as all cases contained at least one of these factors. 32.8% of cases had factors at both of these levels. 67.2% of cases had both a physical processes level also had an environment and surroundings level factor.

A significant negative association was found between local area government planning level and the technical management ($p < .01$) and the physical processes and actor activities levels ($p < .01$). The odds of the presence of a technical management level factor was significantly (6.59 times) larger in cases where a local area government planning level was absent than when it was present ($p < .05$, 4.09 – 10.64). The odds of the presence of a physical processes and actor activities level factor was significantly (4.35 times) larger in cases where a local area government planning level is absent than when it is present ($p < .05$, CI = 1.05 – 17.97).

Discussion

This study has classified the factors involved in a series of led outdoor activity incidents using Rasmussen's Accimap framework in order to test the notion that, in addition to instructor, participant, and environmental causal factors, the incidents that occur during led outdoor activities have contributory factors from across the overall led outdoor activity system. First and foremost, the analysis led to the identification of contributing factors across all levels of the led outdoor activity system. Although the frequency of contributing factors at the higher systems levels was low, factors from all levels were identified.

With regard to the three key tenets of Rasmussen's risk management framework, the analysis confirmed the presence of them across the incidents analysed (although it is acknowledged in only small numbers). First, the framework argues that performance, safety and accidents are emergent properties of a complex systems impacted by the decisions of all of the actors—politicians, managers, safety officers and work planners— not just the front-line workers alone. Our analysis demonstrated that causal factors from the six Accimap levels were present in the incidents analysed. Rather than being primarily the result of participant or instructor actions, the chain of events preceding led outdoor activity injury incidents involve the decisions and actions of many actors from across the overall system. Importantly, these actors can reside outside of the activity providing organisations involved, for example government workers, parents and teachers. Second, the framework argues that accidents are typically caused by multiple contributing factors, not just a single catastrophic decision or action. In the present study, the mean number of contributing factors across the incidents was 4.1 (SD = 2.33), suggesting that led outdoor activity incidents are caused by multiple factors rather than one decision or action in isolation. Third, the framework argues that accidents result from a lack of vertical integration (i.e. mismatches) across levels of a complex socio-technical system, not just from deficiencies at any one level alone. Again, the present study confirmed that causal factors from the six Accimap levels were present in the incidents analysed. Rather than be primarily the result of actions at the instructor/participant level, multiple actions and decisions across all levels of the system can be involved. It is concluded therefore that the systems approach to accident causation applies to led outdoor activity injury incidents. The use of systems analysis frameworks and methods, such as Rasmussen's (1997), is therefore recommended for future led outdoor activity accident and injury incident studies.

Although factors across all levels of the framework were identified, it is acknowledged that there were only a small number of factors identified at the higher levels (Government policy and budgeting, Regulatory bodies and associations, Local area government, activity centre management planning and budgeting, schools and parent, Technical and operational management) when compared to the lower levels (physical processes and instructor/participant activities and equipment and surroundings). Two explanations may be offered for this result. First, it may be that higher level factors do not commonly contribute to incident causation; however, the contemporary accident causation literature would suggest that this is highly improbable. Second, the lack of higher level factors identified may be due to the structure of the database and incident reporting system, whereby causal factors outside of the instructor, participant, environment, and equipment can only be recorded in the incident description and causal narrative fields. That is, incident reporters are provided with multiple choice options for causal factors related to the instructor, participant, environment, and equipment, but not for causal factors outside of these four fields. Without training in the systems approach to accident causation, it is unlikely that reporters would identify causal factors outside of the instructor, participant, environment, and equipment without some guidance. Moreover, it is notable that the systems approach to accident causation is not yet well entrenched within the led outdoor activity domain (Salmon et al, 2010). Compounding the issue, reporters often did not fill in the causal narrative section, or would report that the incident was simply 'an accident' or 'bad luck'. Notably, often reporters would go on to select causal factors related to the participants and instructors from the multiple choice options. This indicates that there may be bias in reporting the causes of incidents in the NZ led outdoor activity sector which could lead to incorrect conclusions.

It useful to compare the present analysis with existing perspectives on led outdoor activity incidents. Various led outdoor accident causation models exist (e.g. Brackenreg, 1999; Davidson, 2007; Meyer, 1979; cited in Davidson, 2007). For example, Meyer (1979; cited in Davidson, 2007) identifies three categories of contributory factors: unsafe conditions (environment), unsafe acts (on behalf of participants) and instructor judgement errors. Whilst the present analysis confirms the presence of all three factors across the incidents analysed, it goes beyond this individualistic perspective to identify contributory factors outside of the instructor, participants, and environment. The requirement for new models of led outdoor activity injury incident causation, incorporating other contributory factors from across the led outdoor activity system, is thus reinforced.

The analysis has implications for preventing injury causing incidents in led outdoor activities. Identification of systems failures is especially useful, since it supports treatment of failures across the system that influence the way in which the led outdoor activity system operates. Many researchers have argued that treatment of wider systems failures, identified through systems-based analyses, is more appropriate than the treatment of local factors at the sharp end of system operation, since the factors creating the front line behaviours are removed following analysis efforts (e.g. Reason, 1990; Dekker, 2002; Leveson, 2004; Rasmussen, 1997). For example, identifying bad decisions or lack of skills on behalf of instructors is useful; however, without a systems analysis, the higher level factors that shaped how the instructor was trained or how they made their decisions is not well understood. Retraining, using the same training system, is not likely to be effective in improving instructors' decision making or skills since behaviour shaping conditions across the wider system are still present.

The present analysis identified a number of common higher level systems failures that played a contributory role in the injury incidents. These included a failure of Governmental organisations to undertake key safety related tasks, various instances of parents and schools failing to provide activity organisers with critical information (e.g. pre-existing injuries, behavioural issues), inadequate risk management and training evaluation systems, inadequate activity policy, poor planning of activities and high participant to staff ratio. Injury incident countermeasures should thus focus on these factors rather than specifically on improving instructor and participant behaviour. For example, for the problem of parents and schools not providing critical information to activity centres, it may be pertinent to improve participant consent and information forms, to better communicate to parents and schools the importance of providing critical information to activity centres, and also to communicate the risks associated with injured participants or participants with behavioural problems engaging in led outdoor activities. Moreover, in the event that they identify problem participants (e.g. injured or ill-behaved), led outdoor activity instructors should be given the power to abort activities or prevent participants from taking part.

The lower level factors identified are also useful to inform systems reform efforts. For example, the present analysis indicates that hazardous terrain was a prominent contributing factor across the incidents analysed. When combined with the identification of poor planning and inadequate risk management systems factors at the higher levels, and also the fact that 67.2% of cases had both a physical processes level and an environment and surroundings level factor, this suggests that the effects of environmental hazards such as terrain should be considered more explicitly in planning and risk management systems and should also form a key part of instructor training programs. Moreover, participants should be given explicit instructions on strategies for coping with hazardous terrain and activity programs should be designed with hazardous terrain management in mind.

In conclusion, this analysis provides evidence that led outdoor activity injury incidents can have causal factors from across the overall led outdoor activity system. When this is added to the existing evidence around large scale led outdoor activity incidents involving fatalities (e.g. Brookes et al, 2009; Salmon et al, 2010) it is apparent that the systems approach is valid as an injury incident causation perspective in the led outdoor activity context. It is argued, therefore, that future efforts undertaken to understand, analyse, and prevent led outdoor activity injury incidents should be underpinned by the systems philosophy on accident causation.

There are a number of pressing requirements to fulfil in order to actualise this paradigm shift. First, injury incident and accident data collection systems underpinned by the systems philosophy are required. Although the database used in the present study was useful, it was notable that specific data on causal factors was only collected in relation to participants, instructors, equipment, and the environment. Without data systems underpinned by the systems philosophy on accident causation, data on the system-wide causes of injury incidents will not be collected. Second, injury incident and accident analysis methods underpinned by the systems philosophy should be developed specifically for the led outdoor activity domain. Without such methods, practitioners will have no means to identify the system-wide causal factors involved in led outdoor activity injury incidents and accidents.

References

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Figure(s)

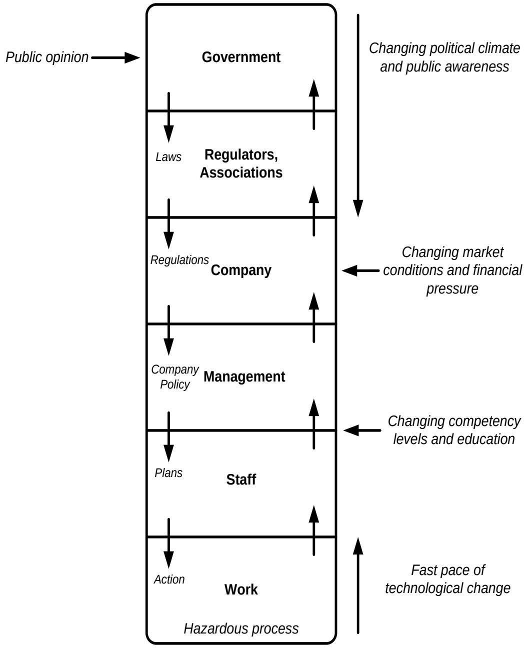

Figure 1. Rasmussen's risk management framework (adapted from Rasmussen, 1997).

1014 Incidents
Number in brackets denotes frequency of occurrence of contributing factor

Government Policy and Budgeting	Government dept failed to fulfill safety responsibilities (12)	Actions of other organisations (1)						
Regulatory Bodies and Associations, schools and parents	Parents failed to provide information (10)	Parents fail to pick up participants (1)	Parents judgement error on fitness for camp (1)	Late arrival of group (5)	School failure to provide adequate information (1)	Industry failure to identify equipment issues (1)	Inaccurate activity rating system (1)	
Local area government, activity centre management, planning and budgeting	Poor/lack of risk management system (45)	Poor staff training evaluation system (33)	Poor/inadequate activity policy (13)	Lack of activity policy (2)	Subcontracting activities to other parties (11)	Poor incident learning systems (3)		
Technical and operational management	Poor planning of activity (58)	Failure to adequately plan for participants with special needs (26)	High participant to staff ratio (26)	Failure to provide appropriate equipment (8)	Poor implementation of risk management procedures (8)	Failure to maintain activity area (8) and equipment (7)	Poor communications with instructors (6) and participants (2)	Lack of staff (4)
Physical processes and instructor/participant activities	Participant factors (1359)	Instructor factors (808)	Group factors (81)	Supervisor factors (19)	Other actors (30)	Student leader factors (4)	Other (6)	
Equipment and surroundings	Hazardous terrain (509)	Lack of equipment (197) and equipment failures (144)	Adverse weather conditions (149) and temperature (76)	Plant hazard (65)	Animal hazard (63)	Visibility (46)	Poor communications with instructors (6) and participants (2)	Poor design of equipment (37)

Figure 2. Summary of contributory factors across led outdoor activity system.

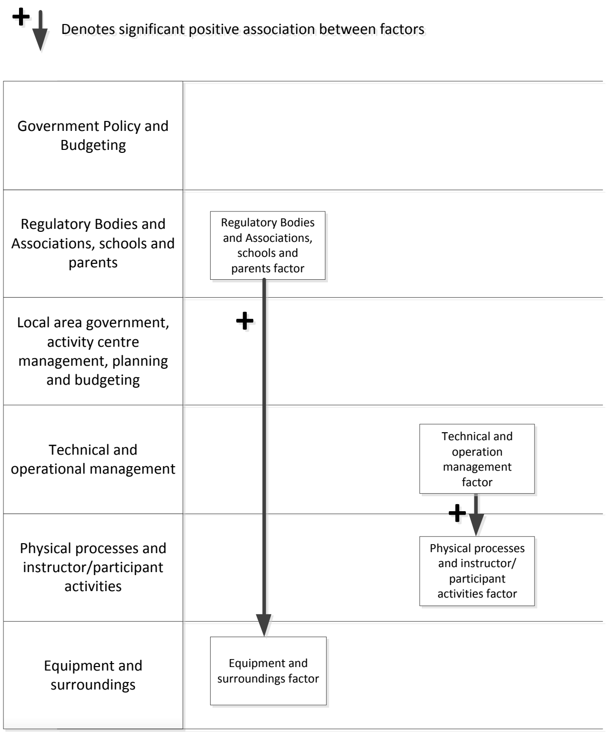

Figure 3. Summary of significant positive associations between factors across different systems level

Table(s)

Table 1. Fields from the OER NID included in the current analysis and response options.

Database field	Question type	Response Options
Causal Instructor	Multiple options can be selected	• Inadequate physical condition • Inadequate mental condition • Inadequate emotional condition • Inadequate health – hygiene or medical • Pre-existing condition • Judgement error • Inadequate supervision • Inadequate training/experience • Failure to follow policies • Improper motivation • Other
Causal Participants	Multiple options can be selected	• Inadequate physical condition • Inadequate mental condition • Inadequate emotional condition • Inadequate health – hygiene or medical • Pre-existing condition • Judgement error • Inadequate supervision • Inadequate training/experience • Failure to follow policies • Improper motivation • Other
Causal Equipment	Multiple options can be selected	• No equipment • Wrong equipment • Faulty equipment, inadequate design, other
Causal Environment	Multiple options can be selected	• Adverse weather • Inadequate visibility/dark • Terrain • Water • Animal/insect/plant • Other
Incident description	Open text response	Describe what happened (e.g. Sequence of events, injuries and other harm, people, distances, times, sizes, etc to present a clear picture of the incident).
Causal narrative	Open text response	Explain in detail what you think caused the incident.

Table 2. Frequency and percentage of incident outcomes by activity type

Activity Type	Injury		Illness		Near Miss		Fatalities		Total	
	n	% within activity	n	% within activity	n	% within activity	n	% within activity	n	% of total cases
Walking/Running	166	65.9	27	10.7	62	24.6	1	0.4	252	24.9
Boating	76	53.9	14	9.9	50	35.5	4	2.8	141	13.9
Camping	39	30.2	78	60.5	13	10.1	0	0	129	12.7
Climbing	43	44.3	3	3.1	50	51.5	1	1.0	97	9.6
Free time	65	90.3	7	9.7	2	2.8	0	0	72	7.1
Ropes	32	37.2	6	7.0	48	55.8	0	0	86	8.5
Swimming	32	66.7	6	12.5	11	22.9	0	0	48	4.7
Initiatives	41	91.1	1	2.2	3	6.7	0	0	45	4.4
Caving	21	61.8	9	26.5	12	35.3	0	0	34	3.4
Cycling	27	81.8	1	3.0	5	15.2	0	0	33	3.3
Skiing/Boarding	21	91.3	2	8.7	0	0	0	0	23	2.3
Ball sports	10	90.9	1	9.1	0	0	0	0	11	1.1
Motor bikes	1	16.7	0	0	5	83.3	0	0	6	0.6
Horse riding	3	75.0	1	25.0	1	25.0	0	0	4	0.4
Weapons	4	100	0	0	0	0	0	0	4	0.4
Miscellaneous	14	48.3	5	17.2	10	34.5	0	0	29	2.9

Table 3. Number of actors involved in each incident by activity type

Activity type	Participants		Qualified Instructors		Parent/Volunteer Helpers		Supervisors	
	M	SD	M	SD	M	SD	M	SD
Ball sports	52.45	40.40	2.64	3.64	3.45	2.16	1.45	1.04
Boating activities	11.20	8.08	0.27	0.63	1.18	1.47	1.72	1.72
Camping activities	36.64	68.73	0.41	1.48	3.60	6.65	2.81	3.94
Caving	9.71	3.22	0.06	0.34	0.65	0.88	1.71	0.91
Climbing activities	11.11	4.88	0.52	1.77	1.27	1.60	1.79	1.28
Cycling	9.97	5.94	0.70	1.90	0.94	0.86	1.18	0.68
Free time	20.74	28.64	1.44	2.58	2.81	4.66	1.18	2.16
Horse riding	7.00	12.68	0.75	1.50	0.50	0.58	4.25	5.25
Initiatives	18.96	18.00	0.62	1.42	2.31	4.27	1.47	1.52
Miscellaneous	13.72	12.19	0.69	1.31	1.00	1.31	2.38	4.34
Motor bikes	1.33	1.21	-	-	-	-	-	-
Ropes	14.08	9.07	0.48	1.16	1.37	1.53	1.63	0.98
Skiing/Boarding	18.70	11.76	0.74	1.63	1.78	1.09	1.43	1.20
Swimming	13.21	7.33	0.56	1.20	1.42	1.27	1.10	0.81
Walking/Running activities	17.76	18.32	1.31	3.14	0.93	1.38	1.37	1.02
Weapons	11.00	2.00	1.00	0.00	0.75	0.50	1.00	0.00

Table 4. Frequency and percentage of injury types by actual and potential severity

Injury Type	Frequency	% of total cases	Actual Severity (1-10, 10 = multiple fatality)		Potential Severity	
			M	*SD*	*M*	*SD*
Sprain	138	23.15	3.42	1.00	4.63	1.24
Laceration/Cuts	74	12.42	3.36	1.01	4.58	1.38
Fracture	64	10.74	5.23	0.66	5.80	1.37
Bruise	57	9.56	2.53	0.93	4.58	1.91
Unclassified	54	9.06	2.61	1.71	4.00	2.38
Muscle Strain	36	6.04	3.50	1.16	4.78	1.55
Burn	26	4.36	3.42	0.95	4.62	1.36
Concussion	23	3.86	3.91	1.24	5.57	1.59
Skin Abrasions	16	2.68	2.50	0.73	3.88	1.31
Head Injury	16	2.68	3.44	1.36	5.00	2.16
Dislocation	23	3.90	4.43	1.16	5.43	1.24
Punctures	15	2.52	1.67	1.35	5.00	1.51
Insect sting	10	1.68	2.50	1.27	5.00	2.45
Blister	9	1.51	3.11	0.33	3.33	0.71
Eye Injury	8	1.34	2.88	0.99	5.00	1.41
Dental	8	1.34	3.75	1.16	4.25	0.71
Other	19	3.22	4.09	-	5.41	-

Table 5. Frequency and percent of causal factors identified at the government policy and budgeting level

Key theme	n	% of all incidents
Government department responsible for conservation - track layout incorrectly marked on maps	6	.59
Government department responsible for conservation - failure to remove insect hazard	5	.49
Government department responsible for conservation - failure to repair track	1	.10
Actions of other companies	1	.10

Table 6. Frequency and percent of causal factors identified at the regulatory bodies and associations level

Key theme	N	% of all incidents
Parents fail to inform activity organisers of medical condition	6	0.59
Late arrival of group	5	0.49
Parents fail to inform activity organisers of pre-existing injury	2	0.20
Parents fail to inform organisers of behavioural issues	2	0.20
Parents fail to pick participant up from activity	1	0.10
Parents judgement error that participant is fit for camp	1	0.10
Consultation with industry members failed to identify equipment problems	1	0.10
Rating system did not accurately reflect difficulty of climb	1	0.10
Inadequate information from school	1	0.10

Table 7. Frequency and percent of causal factors identified at the local area government planning and company level

Key theme	N	% of all incidents
Poor/lack of risk management systems	45	4.44
Poor staff training evaluation systems	33	3.25
Poor or inadequate policies on activities	13	1.28
Subcontracting activities to other providers	11	1.08
Poor incident learning systems (e.g. incident reporting, hazard assessment)	3	0.30
Lack of policies on activity	2	0.20

Table 8. Frequency and percent of causal factors identified at the technical and operational management level

Key theme	N	% of all incidents
Poor planning of activity	58	5.72
Poor planning for participant abilities special needs	26	2.56
High participant to staff ratio	26	2.56
Lack of poor instructor management	10	0.99
Failure to provide appropriate equipment	8	0.79
Poor implementation of risk management procedures	8	0.79
Failure to maintain activity area	7	0.69
Equipment serviceability	7	0.69
Poor communication with instructors	6	0.59
Lack of staff	4	0.39
Poor communication with participants	2	0.20

Table 9. Frequency and percent of causal factors identified at the physical processes and actor activities level

Higher level category	Factor	total	%
Participant factors	Participant unsafe act	302	29.78
	Participant pre-existing condition	243	23.96
	Participant lack of skills technique	229	22.58

	Participant failure to follow instructions	132	13.02
	Participant judgement error	114	11.24
	Participant experience practice	85	8.38
	Participant attitude	58	5.72
	Participant physical condition	56	5.52
	Participant illness	26	2.56
	Participant lack of awareness of hazard	21	2.07
	Participant lack of preparation	20	1.97
	Participant characteristics	11	1.08
	Participant lack of knowledge	2	0.19
	Participant lack of training	2	0.20
Instructor factors	Instructor judgement error	300	29.58
	Lack of poor supervision	165	16.27
	Instructor inadequate supervision of participants	144	14.20
	Instructor lack of poor instructions to participants	46	4.53
	Instructor attitude	29	2.85
	Instructors inadequate training experience	24	2.36
	Instructor fail to follow policies procedures	21	2.07
	Instructor lack of planning	13	1.28
	Instructor lack of skills technique	11	1.08
	Instructor pre-existing condition	10	0.98
	Instructor poor group management	8	0.78
	Instructor poor hazard awareness	8	0.78
	Instructor unsafe act	8	0.78
	Instructor lack of knowledge	7	0.69
	Instructor physical condition	5	0.49
	Instructor fail to check equipment	4	0.39
	Instructor poor implementation of safety systems	3	0.29
	Instructor poor lack of leadership	2	0.19
Group factors	Poor communication	51	5.02
	Group dynamics	20	1.97
	Lack of teamwork	10	0.98
Supervisor factors	Supervisor lack of skills technique	4	0.39
	Supervisor unsafe act	4	0.39
	Supervisor judgement error	3	0.29
	Supervisor poor instructions	3	0.29
	Supervisor attitude	2	0.19
	Supervisor lack of knowledge	1	0.09
	Supervisor poor hazard awareness	1	0.09
	Supervisor poor implementation of safety systems	1	0.09
Other actors	Driver unsafe acts	12	1.18
	Teacher actions	8	0.78
	Actions of members of the public	10	0.98
Student leader factors	Leader attitude	2	0.19
	Leader inadequate training experience	1	0.09
	Leader physical condition	1	0.09

Other	Bad luck	6	0.59

Table 10: Frequency and percent of causal factors identified at the equipment and surroundings level

Key theme	N	% of all incidents
Hazardous terrain	509	50.20
Lack of equipment	197	19.43
Adverse weather conditions	149	14.69

Equipment failures	144	14.20
Temperature	76	7.50
Plant hazard	65	6.41
Animal hazard	63	6.21
Visibility	46	4.54
Poor design of equipment	37	3.65