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Dynamic risk management in fire and rescue emergency operations

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Dynamic Risk Management in Fire and Rescue Emergency Operations

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ABSTRACT

Firefighting is an inherently dangerous occupation involving numerous risk sources, unique contexts, multiple personnel and rapidly changing environments. Firefighting operations are dynamic in nature yet require calculated risk taking and structured command to prevent the realisation of potentially catastrophic outcomes to both casualties and rescuers. The notion of "dynamic risk management" is a term that has gained popularity throughout fire services worldwide, yet the process of dynamic risk management is typically poorly articulated. This study demonstrates 'dynamic risk management' is a misnomer, with risk management being a defined process applied within the context of dynamic emergency response. Failure to recognise this and respond accordingly may leave fire services exposed to adverse findings should adverse consequences be realised. Further, this study tested the perceptions of risk held by incident controllers in the Department of Fire and Emergency Services in Western Australia against AS31000, through a combination of qualitative surveys and subsequent Bayesian analysis of reported adverse outcomes resulting from all hazards emergency response. This study found significant variance in risk tolerance between incident controllers and to a lesser degree, variance in the understanding of risk as defined by AS31000. Bayesian statistical analysis identified reportable adverse outcomes were almost certain to occur across the majority of firefighting activities, whilst potential worst case outcomes were rarely historically realised. The results of this study demonstrate that it is critical for firefighting organisations to have documented risk thresholds and to provide greater education of risk management in dynamic situations to incident controllers of all ranks.

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Date……………………………………….

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1.0 Introduction

1.1 Background to the Study

Emergency services personnel respond to thousands of dynamic emergency incidents across Australia each week. As part of this response each incident controller must rapidly and correctly manage risk within the challenging and dynamic emergency environment. Despite the intense pressures associated with risk management in these environments, little formal research has been completed to determine whether current risk management practices are compliant with International/Australian Standard 31000:2009 – Risk management principles and guidelines (AS31000).

The primary objective of this study is to determine whether current risk management practices in dynamic emergency incidents within the Department of Fire and Emergency Services (DFES) in Western Australia are compliant with AS31000. A subsequent objective is to define the internal context of dynamic risk management within the operational incident management and response section of DFES.

In order to evaluate current practices within DFES, first a systematic review of internal and external literature is presented. Next, the results of qualitative semi-structured interviews of participating incident controllers are analysed and compared with organisational literature and policies to determine current practices and define to the internal risk context applicable to the study group. Finally, Bayesian statistical analysis of historical incident occurrence data is discussed to further define the internal risk context and to facilitate improved practice.

1.2 Significance of the Study

This study is significant in that it is the first of its kind in Western Australia and potentially nationwide. Results may not only serve to enhance risk management in dynamic emergency environments, but to also reduce the incidence of injury to responders through the harmonisation and documentation of risk tolerance and acceptable practice.

1.3 Research Question

Is risk management in dynamic emergency operations in the Western Australian fire and emergency service compliant with AS31000?

1.4 Hypotheses

Null Hypothesis (H_0)

Risk management during dynamic emergency operations in the Western Australian fire and emergency service is compliant with AS31000.

Alternate Hypothesis (H_1)

Risk management during dynamic emergency operations in the Western Australian fire and emergency service is not compliant with AS31000.

2.0 The Literature

2.1 The Standard of Risk Management

Australian and international standards are collaboratively developed by subject matter experts, industry and other invested stakeholders in order to provide benchmarks for construction or processes. When referenced by relevant local legislation these standards become mandatory, without such reference the standards serve the same purpose albeit only when adopted voluntarily by organisations. One such standard is AS31000 which provides the architecture for the management of risk regardless of circumstance or consequence. Failure by organisations or individuals to manage risk in accordance with AS31000 does not necessarily equate to adverse outcomes. However, criticism and adverse finding may occur where AS31000 is not followed and an adverse outcome eventuates, especially where consequences are severe and may have been avoided. In occupations involving rapidly changing and multiple risk sources, multiple personnel and the potential for the loss of life there is little margin for error in managing risk and consequently, compliance with AS31000 becomes vital. This chapter examines risk in the context of firefighting operations.

2.2 Defining Risk

Risk and the process of risk management applicable to all situations are defined in detail within AS31000; SAHB 436:2013 Risk management guidelines – Companion to AS/NZS ISO 31000:2009 (SAHB 436); and SAHB 89:2013 Risk management – Guidelines on risk assessment techniques (SAHB 89). Whilst the term 'risk' is often incorrectly used concurrently with or instead of the term 'hazard', risk is specifically defined as the "effect of uncertainty on objectives" (AS31000 s2.1). Risk is not an event (SAHB 436, s2.1). It is not an explosion,

fire or other emergency. Risk cannot be expressed as either positive or negative, but rather as the likelihood of a consequence, positive or negative, occurring. When applied to emergency response it is essential to appreciate that incidents are dynamic, occurring within an environment subject to constant change and therefore the level of uncertainty and therefore risk, must be constantly reassessed.

Risk is often inappropriately described (SAHB 436). To appropriately describe risk three elements must be specified:

1. The objective(s) being referred to;
2. The particular source of uncertainty; and
3. How the source of uncertainty may lead to consequences.

In the emergency response setting an example of a statement of risk may include:

There is the potential that firefighters will have to rescue casualties involved in a high speed vehicle crash, which in turn will cause injury or harm to the firefighters from mechanical, thermal and chemical hazards preventing all firefighters completing the rescue unharmed.

In this statement:

1. The objective is firefighters completing the rescue do so unharmed;
2. The source of uncertainty (risk source) is the vehicle rescue; and
3. Exposure to mechanical, thermal and chemical hazards may lead to the consequences, i.e., firefighters getting injured.

From this example it becomes clear that during dynamic emergency incidents firefighters must be acutely aware of the objectives to be met in the first instance. This requires comprehensive guidance at an organisational level to establish objectives well before an incident occurs. Although specific standing objectives may vary between fire services, the general objectives of the preservation of life, property and the environment are common between services. These general objectives are typically not further defined. Nor are overarching statements of risk evident in any of the Australian or international fire brigade literature that satisfies the criteria of SAHB 436.

2.3 Risk Management and Managing Risk in Dynamic Situations

'Risk management' refers to the structure (principles, framework and process) for managing risk effectively whilst 'managing risk' refers to the application of that structure to the decision making process (SAHB 436, s2.9). Whilst DFES Directive 0.0 "The Fundamentals of DFES Operations" (date unknown) provides some guidance in relation to time poor decision making during emergency management and utilises the word "risk", it provides no discussion or commentary as to the organisational definition of risk or risk management process. The risk management process detailed in AS31000 (Figure 1) provides the architecture for decision making involving risk and must be applied in every situation, including emergency response, for risk to be deemed to have been considered sufficiently (SAHB 436, p44).

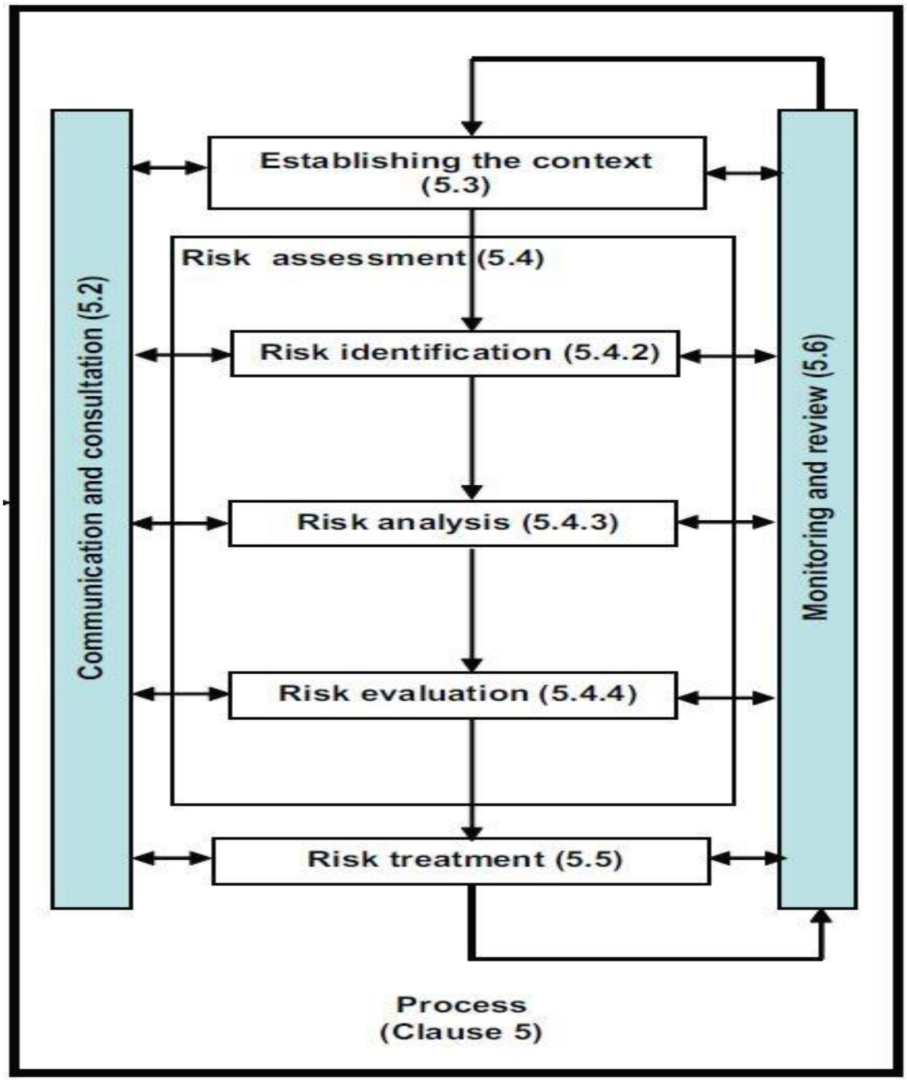

Figure 1: AS31000 Risk management process (AS31000, figure 1)

SAHB 436 (s5.1.2) identifies the process of risk management and must be fully applied in every situation regardless of the complexity of the issues faced, the dynamic nature of the operating environment and the time available to make required decisions. Further, SAHB 436 (p45) provides the following example which may be interpreted as being directly applied to the firefighting context:

> *"A military special forces section leader might have a split second in which to make a tactical decision on which personal wellbeing and that of subordinates as well as the success of the mission, might depend. In that time the leader must recall the objectives, appreciate the external and internal environment, assess the risks, consider the options, review those against the objectives and take the appropriate action. Despite the very short decision making window, the quality of each of these steps must be of the highest standard."*

Failure to sufficiently understand risk or to apply the entire risk management structure to dynamic decision making in the emergency environment can result in decisions that exacerbate rather than mitigate adverse consequences. Should adverse outcomes eventuate it may also lead to post incident scrutiny of the decisions made by incident controllers. Existing studies suggest risk assessment in accordance with AS31000 may not occur during frontline emergency response (Ash & Smallman, 2008; Sadler, Holgate & Clancy, 2007).

2.3.1 Establishing the Context

The term 'context' applies to both the risk management framework (architecture) as well as the process of risk management. In terms of architecture, the context includes both the external and internal environment in which the organisation or individual operates (SAHB 436, s2.8). In order to establish context effectively, it is necessary to clearly define both the objectives to be achieved and the parameters to be considered whilst managing risk. Failure to clearly establish the context may lead to the entire risk management architecture and process being flawed as a consistent approach cannot be achieved. The stages of establishing the context are illustrated in Figure 2.

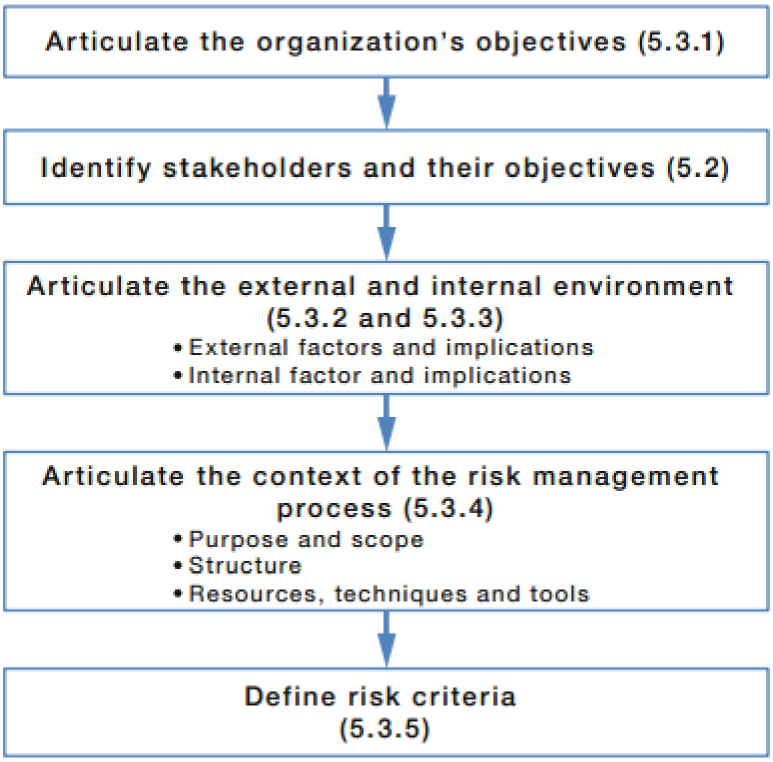

Figure 2: HB 436 Establishing the context.

2.3.1.1 Articulating the organisation's objectives.

DFES (2013c) identified four primary objectives of the organisation as the preservation of life, property, critical infrastructure and the environment (in that order). These objectives were found to be identical to those of other departments in both Australia and internationally (NZFS; 2008, QFRS, 2008). Further, DFES (2015d) identified the following objectives applied to certain operational incidents in the order they are listed:

1. Rescue (effect rescue of human life);
2. Exposures (prevent adjacent assets including houses and infrastructure becoming impacted by fire);
3. Containment (contain the fire to the smallest area or structure possible);
4. Extinguishment (extinguish the fire);

5. Overhaul (ensure the hazard is eliminated);
6. Ventilate (removing smoke);
7. Environment (protect the environment from the hazard and firefighting activities); and
8. Salvage (prevent avoidable damage).

2.3.1.2 Identify stakeholders and their objectives

Whilst no literature specific to the risk attitudes of firefighters in the Western Australian fire service exists, Fender's (2003) American study identified the following objectives were common amongst career and volunteer firefighters:

- Not to let fellow firefighter's down; and
- Live up to community expectations.

These objectives appear to support the high personal risk threshold observed in firefighters as reported by Penney (2013) and Moore-Merrill et al. (2008) and discussed further in section 4 of this report.

2.3.1.3 Articulating the external and internal environments

The external environment includes regulatory or legislative requirements to be adhered to as well as community and political attitudes that directly influence the internal environment. The external environment provides overall strategic parameters within which operations must remain to be deemed publicly acceptable and to be deemed lawful. This helps define the architecture that governs the interpretation and application of the risk management process.

The internal environment includes organisational attitudes, the beliefs of the individual risk manager, and the specific purpose and setting for the particular application of the risk management process at a specific time and place. Where organisational risk attitudes are not defined or communicated the individual risk manager inherently relies upon their own risk thresholds.

2.3.1.4 The external context of firefighting operations

Regardless of the nature or location of an emergency, firefighting remains an occupation and thereby subject to the same laws as any other workplace (Occupational Safety and Health Act, 1984 - OSH Act). Section 19 of the OSH Act details the requirements of employers to provide a safe work environment 'so far as is practicable.' Whilst certain exemptions are made for dangerous Police work under Section 4A of the OSH Act, no such exemptions exist for firefighters at fire, rescue or other related emergency incidents. During firefighting operations it may be considered that the employer is actually the fire brigade Commissioner or other senior ranking officer who is unlikely to be physically present at the scene of an emergency incident. This does not exempt the employer from providing a safe workplace including safe systems of work and information, instruction and training (COSH, 2005). Employees at the incident, in particular those in positions of command or control, also have responsibilities under Section 20 of the OSH Act. These responsibilities include taking:

> *"take all reasonable care –*
>
> *a) To ensure his or her own safety and health at work; and*
>
> *b) To avoid adversely affecting the safety or health of any other person through act or omission at work."*
>
> OSH Act s20

In considering whether an employee has met their duties under the OSH Act, courts consider how a 'reasonable person' may have acted in that particular case. COSH (2005, p8) identifies that a value judgement "is made on the values of the society of the day" and the more a person is aware of associated risk, the greater their obligation to manage that risk.

Fire brigade literature (DFES, 2013c) identifies that usual duties of operational officers involve performing risk assessments, safeguarding firefighters from harm and controlling operations at emergency incidents. In Western Australia, the Department of Fire and Emergency Services (2013b) identifies Fire and Rescue Service firefighters as responsible for emergency response to:

- road crash rescue;
- structure fire;
- bushfire;
- chemical and hazardous material management including gas leaks; and
- flood, storm or tempest.

The literature indicates that firefighters and officers are professionals responsible for the response and management of a wide range of dangerous emergency incidents. In consideration of the relevant legislation, firefighters and officers may be held to a higher obligation to provide a safe workplace during dynamic and dangerous situations. In order to achieve this as part of their normal work role they are provided with enhanced training and specialist equipment.

In addition to the defined work role and specific focus on risk management during emergency response in dynamic situations, firefighters are also held in special regard by the community.

In the absence of formal research, popular commercial literature was reviewed to determine community opinion towards the firefighting profession. A decade of national popular opinion polls (Flynn, 2014) identifies firefighters as being the second most trusted profession by the Australian community (the first being paramedics). Whilst far from formal research, these public opinion polls demonstrate firefighters are held in high regard by the people they serve. The gravity of this external regard also serves to develop the internal context for firefighters on the ground in the form of pressure to make difficult decisions in order to live up to community expectations.

2.3.1.5 The firefighting culture – defining the internal context

The internal context as applied to firefighting may be divided into two distinct levels. The first being the organisational attitudes, policies and operational frameworks that provide the structure for the fire service. The second being the internal culture of the firefighting stations and crews themselves.

Organisational culture is indoctrinated into firefighters from the first day they commence as trainees. Discipline, obedience, calculated risk taking and teamwork are part of the founding traits imbedded into probationary firefighters by their instructors. Development of these traits is supported by an overarching organisational attitude reflected in the manner training is administered, conducted and resourced. Whilst an abundance of Australian fire service tactical training literature was located, a striking absence of Australian fire service risk ideology was identified.

other than that comprehensively detailed by the UK Fire Service (see section 2.4 of this report) was noted. Internationally, the "Safe Person Concept" was identified in various forms (IFAC, 2012, NFPA, 2013; NZFS, 2008) which partially defines risk attitudes amongst fire services. Summarised, the New Zealand fire service interpretation of the Safe Person Concept (NZFS, 2008) is:

"We may risk our safety, in a highly calculated manner, to protect saveable lives.
We may risk our safety a little, in a very careful manner, to protect saveable property.
We will not risk our safety for lives or property that are obviously lost."

Whilst these three sentences clearly articulate the risk attitudes and thresholds of the New Zealand Fire Service's, further definition of the term "calculated" is not provided. The absence of this definition suggests that a subjective and qualitative assessment may be considered acceptable by the fire service hierarchy in identified scenarios. Whilst senior fire service hierarchy are unlikely to be present at an operational incident in all but the most extreme cases, the culture they create is carried within each operational person onto the incident ground and may be considered to have a significant impact on the way an incident controller manages risk.

Perhaps the more intimate internal firefighter culture that affects risk management during emergency operations is the culture amongst firefighting crews. Firefighters spend a significant amount of time together during both emergency incidents and routine station life (Childs, Morris & Ingram, 2004). In this environment indoctrinated traits established by organisational culture invariably flourish and form a unique environment that has the capacity to directly influence an incident controller's management of risk during dynamic emergency operations.

Firefighters have long been seen as “heroic, blue collar battlers” (Childs, Morris & Ingham, 2004) where time honoured practices, as opposed to formal research and evidence based practice, have formed the basis for both strategic and tactical response by firefighters at the ‘coal face.’ This reliance on traditional approaches and professional craft knowledge passed down through firefighter generations is viewed with pride amongst many firefighters (Penney, 2013) and serves to build a strong culture and internal context of self-reliance and belief.

Reports released by the National Interagency Fire Centre (1996) and Moore-Merrell et al. (2008) identify an established culture of risk taking amongst firefighters in order ‘to get the job done’ regardless of operational guidelines. This is supported by the findings of Kunadharaju, Smith and Dejoy (2011) who reported (in contrast to most high hazard work) firefighting operations are actively based on hazard engagement, typically compounded by acute time pressures. However, Prochniak (2014), found firefighters are acutely aware of the fragility of time and life. Further, Prochniak (2014, p257) found that “firefighters wishing to pursue a dangerous occupational task must plan their own behaviour, concentrate on the goal, and maintain a temporal distance from the task by focusing on a lack of time pressure.”

Fender (2003) identified multiple firefighter specific traits that directly affected their risk tolerance. These included:

- The age of a victim - the younger the victim the higher the threshold to personal injury or death;
- Respect for the officer in charge – firefighters were willing to undertake more dangerous tasks if they respected the officer giving a command;
- A sense of pride in taking risks; and
- Expectations of the community.

A previous study into the decontamination practices of firefighters exposed to hazardous and toxic materials (Penney, 2013) also found a tendency amongst firefighters to perceive hazardous incidents as routine if they were encountered and completed without acute health effects becoming evident.

As identified in the literature discussed in this section, firefighting is a unique profession that attracts a certain type of person with a natural tolerance to personal risk. These personnel are then placed in dynamic and dangerous situations whilst surrounded by a culture of risky behaviour, arguably as a result of occupational necessity. This environment is potentially further fuelled by the weight of perceived public expectation and human distress in traumatic circumstances. Whilst this internal context may actually enhance the capacity of firefighters to complete the job required, it may also lead to behaviour that may be deemed to be inappropriate in accordance with the external context, especially when adverse outcomes eventuate.

With the possible exception of community attitude, the external context applicable to the firefighting environment is the same as that applied to other workplaces. As an employer, fire services are required to provide a safe workplace and supervisors have a legal duty of care to employees under their management. Further, as fire services personnel are expected to work in critical, hazardous and dynamic environments (DFES, 2012a, 2012b, 2013b, 2015a, 2015b, 2015d) it may be argued that fire service incident controllers have a greater duty of care to their crews than would be expected of other community members in that same situation. The increased accountability of the external context must be compared to the effects of the internal context which supports risk taking behaviour with limited formal quantified guidance.

Whilst it is acknowledged that the dynamic emergency environment requires a significant amount of flexibility for incident controllers, the absence of formal guidance in the literature reviewed suggests a gap between external statutory requirements and internal expectations within fire services. Awareness of the differences between external and internal contexts and how each may affect an incident controller's perceptions and firefighter actions on the incident ground would likely only enhance the ability of an incident controller to better appreciate an emergency situation and enhance the management of associated risk. This has the subsequent potential benefit of reducing firefighter injuries and fatalities as a consequence of occupational events.

2.3.2 Risk Identification

Risk identification is "the process of finding, recognizing and describing risks" (SAHB 89, s3.3). Whilst traditional risk identification may involve data analysis, modelling, testing and research, the dynamic and often critical nature of emergency response requires the process of risk identification to be undertaken in an instantaneous yet accurate manner. As Kunadharaju, Smith and Dejoy (2011) identify, "there is little protective redundancy in firefighting" and emergency situations often change with little or no forewarning.

The dynamic nature of emergency incidents also requires risk identification to be undertaken frequently; with each risk identification and subsequent analysis occurring as a single event at a point in time as opposed to being an ongoing sustained practice throughout the duration of an incident. It may therefore be argued that the term "dynamic" in dynamic risk assessment must only refer to the constantly changing emergency event as opposed to an ongoing yet changing structure of risk management.

SAHB 89 identifies that the process of risk identification may take the form of structured techniques which involve the use of foresight in conjunction with existing knowledge to develop a series of 'what if' questions. The 'what if' questions within the literature reviewed were inherently dependent on the incident controller's own personal knowledge and experience as opposed to quantified data or formal evidence based practice (DFES, 2013c, 2015c).

2.3.3 Risk Analysis

Risk analysis (also known as risk assessment) is the "process to comprehend the nature of risk and to determine the level of risk" (SAHB 89, s3.4). The process of comprehension requires the risk manager to be able to adequately interpret risk sources in a structured manner and to subsequently understand the probability and consequences of an event occurring. During even the most rapidly changing emergency situations the risk management framework and structure remains the same. Each risk analysis must be considered a new separate analysis, even if it builds upon a previously and recently completed analysis of the same emergency situation at an earlier point in time.

This realisation is significant because it supports the theory that dynamic risk management does not involve a changing architecture or process of analysis, but rather the same risk management architecture and analysis process applied multiple times during a rapidly changing (dynamic) emergency situation. The risk analysis undertaken during an emergency may therefore comply with AS31000, even if it is required to be supported by extensive pre-incident analysis and preparation.

Risk analysis may either be qualitative, quantitative or a combination of both. However, quantitative analysis requires the analysis of numerical data to determine probability. Risk can then be described as a numerical value by multiplying the sum of incident exposures, statistical probability and consequence weight (Xin & Huang, 2013). Quantitative Risk analysis of this nature requires extensive data and time, therefore it cannot be undertaken within the parameters and constraints of a single emergency incident. This is highlighted in the Australian Capital Territory Emergency Services Authority (date unknown) Dynamic Risk assessment overview statement that "often, rescues have to be performed, exposures protected and hose lines placed before a complete appreciation of all material facts have been obtained" (p2).

Qualitative analysis involves descriptive and often subjective appraisal of risk as described by the assessor. It is often useful when risk treatment strategies involve multiple risks at different levels that cannot be accurately measured on the same quantitative scale (SAHB 89). It is an approach that is identified as being employed during preliminary or scoping assessments. For example, SAHB 89 states that "in cases where the analysis is qualitative, there should be a clear explanation of all the terms employed and the basis for all criteria should be recorded" (p18). Review of fire services literature (ACTEMS, unknown; DFES, 2013a; NZFS, 2018; SACFS, 2014) identified that whilst prioritised objectives of the protection of life, property and the environment were common across jurisdictions, explanations of terminology were largely absent from operational material. Whilst some explanation of qualitative risk was found (DFES, 2013d, 2014) these explanations were found in corporate policies rather than in operational doctrine or procedure.

Quantitative risk analysis relies on the numerical representation and calculation of event probabilities, frequencies and distributions. Considered the epitome of fire risk analysis in the International Fire Engineering Guidelines (ABCB, 2005), probabilistic risk analysis requires detailed and time consuming consideration of all possible outcomes as either a function of incidence, Bayesean probability or life/dollar loss per unit time (Yung, 2008). Such analysis requires availability of substantial high quality data as well as the ability to numerically represent variability within defined confidence levels. Whilst typical quantitative analysis, including fault tree or event tree diagrams, may be particularly useful for pre-incident planning and as a supporting assurance process, their complexity and time required for completion render them impractical for incident ground completion. Review of available literature identified that whilst significant international statistical analysis of fire related fatality and injury data were available (DCLG, 2012; FEMA, 2009, 2011) a total absence of statistical analysis of Australian firefighting injuries and risk management during dynamic operations was noted in both published and internal brigade documentation.

Analysis of implemented controls may be considered to have both qualitative and quantitative components (SAHB 89, SAHB 436). For example, reviews of historical injury data may provide quantitative probabilities pertaining to the effectiveness of certain personal protective equipment in reducing firefighter injuries, whilst fire ground experience may provide an incident controller with valuable insight into the effectiveness of specific tactics in certain situations. Yung (2008) asserts that reliance on qualitative assessment alone must be considered fundamentally flawed because subjective judgements cannot be verified and may often differ between operators. Further, the same operator may make different decisions given the same situation at various points in time. The use of a mixed approach may provide the

benefits of pre-incident quantitative data analysis supporting the rapid qualitative analysis conducted by incident controllers in dynamic emergency situations. This type of approach can be represented by a Bow-Tie analysis (SAHB 436) allowing the predetermined risk sources and prioritised event causes to be the focus of qualitative assessment during dynamic emergency situations (see figure 5, p72).

Decisions made on the incident ground have previously been found to be reactionary rather than considered (Ash & Smallman, 2008; Sadler, Holgate & Clancy, 2007) or to be adapted from previous experience at similar situations or incidents potentially without thorough analysis (Tissington, 2004). Jacobs (2010) as well as Loflin and Kipp (1997) suggest dynamic risk management in the emergency rescue context is often restricted to a qualitative selection of tactics guided by tacit professional craft knowledge as opposed to quantified risk assessment and evidence based practice as part of the entire risk management process. In order to achieve consistency with AS31000, it is suggested incident ground decisions must be made using a combination of quantified historical statistical analysis and qualitative personal judgement by the incident controller.

2.3.4 Risk Evaluation

Evaluation of risk may only be correctly undertaken if there are clear criteria (context and risk threshold) against which the evaluation occurs. As previously identified, clear and concise risk criterion specific to dynamic emergency situations are not prevalent throughout fire services. Consequently, incident ground controllers may be considered to be largely self-reliant on their own decision making processes and internal judgement.

Klein's Recognition-Primed Decision (1989) and Rasmussen's Decision Ladder (1976, cited in Naikar, 2010) represent two accepted models representing the decision process of experienced personnel in dynamic situations. Both models are dependent on a high level of expertise from the decision maker and the ability to process information in a structured sequence that characterises rational, knowledge-based behaviour (Naikar, 2010). Neither model references the application of risk management into the decision making process or how prior exposure may influence risk tolerance and the cognitive process. This suggests that unless risk management forms part of the inherent expertise of the practitioner it will not be considered. Further, inappropriate or insufficient understanding and consideration of risk may leave emergency services personnel with potentially dangerous familiarity with the hazards they face (Sadler, Holgate & Clancy, 2007).

Differences in the identification of objectives and the willingness to accept and retain risk (risk tolerance) between strategic and tactical levels within an emergency services organisation, as reported by Ash and Smallman (2008) and Jacobs (2010), may result in risk management decisions being made by incident controllers that could be later considered to be inappropriate or unjustified. Further, Ash and Smallman (2010) identified the perception by emergency services personnel that strategic (organisational) decisions and guidance may hinder achievement of goals at a tactical level and actually contribute to inappropriate risk management during emergency response.

2.3.5 Risk Treatment

Risk treatment involves the application of mitigating processes, systems or other inhibitors to reduce the likelihood or consequence of an event occurring (AS31000, SAHB 89, SAHB 436).

Consequences of inaccurate identification of risk and subsequent analysis and treatment can be catastrophic with Moore-Merill *et al* (cited in Ash and Smallman, 2010) identifying 19% of all firefighter deaths in the United States between 2000 and 2005 being a direct result of human error. In the context of firefighting operations, risk treatments (also known as controls) may be considered in the contextualisation of the traditional hierarchy of controls.

The hierarchy of controls relates to the application of risk barriers or treatments that either reduce the likelihood of an event occurring or reduce the severity of a consequence (Robinson et al., 2010. The higher the order of the treatment, the more it is deemed to be effective. A contextualised hierarchy of controls is illustrated in Figure 3. At the top of the hierarchy is "elimination" which refers to the removal of the risk source. In the firefighting context this may be viewed as pre-operational actions such as arson prevention or road safety campaigns. During an emergency incident "elimination" may include the decision not to commit crews, but rather to isolate a fuel source and permit it to 'burn out' so that lives are not endangered.

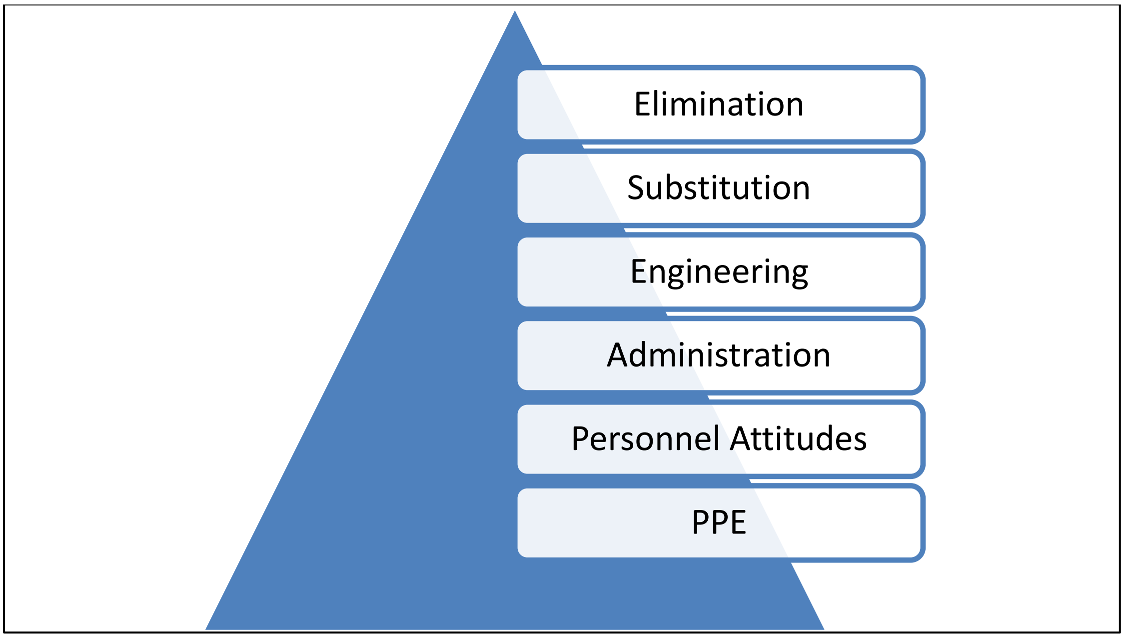

Figure 3: Contextualised Hierarchy of Controls

Next in the hierarchy is "substitution" which is difficult to translate to the firefighting context because firefighters often respond to emergency situations where time and resourcing restrictions are encountered. It may be considered that a decision to use defensive firefighting strategies, as opposed to offensive internal firefighting strategies, may meet the definition for substitution because even though the risk source is not eliminated, the approach to resolving the incident is specifically varied in a manner that reduces the potential for an adverse event to occur.

"Engineering" controls are those that isolate assets from the risk source. In the firefighting context this may only be partially achieved because there is likely to be a requirement for at least several firefighters to be present within the 'hot' zone (DFES, 2012b, 2015b, 2015d) and this remains essential to resolving many dynamic emergency situations. Isolation occurs through the implementation of controlled access to areas within an emergency incident that are the greatest risk source through Entry Control Officers and physical demarcation (DFES, 2015a, 2015b). Despite the use of isolation controls at emergency incidents, which may reduce the potential for greater numbers of adverse outcomes, incident controllers are still required to commit sufficient firefighters into hazardous situations in order to resolve the emergency.

"Administrative" controls are the policies, procedures and 'doctrine' that provide organisational guidance as to the appropriate manner in which to resolve a dynamic emergency situation. Extensive fire services literature in this area was found (DFES, 2013a, 2013d), however, an absence of established risk criterion or documented risk thresholds was also noted. No reason for this absence was found.

“Personnel attitudes” are an addition to the traditional hierarchy of controls and may be considered a critical component to the contextualised hierarchy of controls within the firefighting environment. It may be considered that personnel attitudes are significantly influenced by the internal context in which they evolve (Lloyd, 2005, Lloyd, 2008) and the internal context of firefighters is particularly influential. Without specific guidance and ongoing detailed training, personnel may be encouraged (or even forced) to behave in a particular way “not because they believe in that form of behaviour but it is seen as the way out of a predicament” (Hutchinson, 2010, p15). It is therefore surmised that the attitude of individual firefighters under the command of an incident controller must be considered in the contextualised hierarchy of controls. Whilst good attitudes will afford some benefit for the reduction of the likelihood of an adverse outcome, poor attitudes will inevitably increase the potential for failure to implement or abide by other controls and therefore increase both the probability and severity of adverse outcomes on the incident ground.

“Personal protective equipment” colloquially known as PPE within fire services represents the final line of defence between personnel and an adverse outcome. Whilst some PPE may in fact reduce the potential for realisation of an adverse effect, for instance breathing apparatus theoretically preventing a firefighter inhaling toxic smoke and products of combustion (DFES, 2015a, 2015b), it must also be considered that the presence of PPE may result in firefighters undertaking greater risk taking behaviour due to a perception that the PPE affords them complete or excessive levels of protection (Penney, 2013).

2.3.6 Monitoring, Review and Communication

By definition, dynamic emergency situations constantly change. Regardless of whether an incident involves a leaking hazardous material, multi storey apartment fire or a heavy vehicle crash, the number and level of hazards will change as the incident evolves (DFES, 2012a, 2012b, 2013a, 2013b, 2015a). Monitoring, review and communication may be considered to occur on two distinct levels appropriate to the internal and external context.

Within the internal environment of a dynamic emergency incident the incident controller must constantly reapply the risk management architecture within the operational constraints they face. This cyclical process is illustrated by Bailey (2007) in Figure 4 and represents the current approach adopted by Australian fire services to dynamic risk management as supported in the literature reviewed. As previously discussed, the available time with which to make decisions and subsequently communicate these decisions to all persons on the incident ground is likely to be limited, whilst the potential consequences of an incorrect decision may be catastrophic. The monitoring and review process may also be limited to a single decision maker or the Incident Management Team depending on the severity and longevity of an incident (DFES, 2013a, 2013c, 2015c). Whilst the Incident Management Team has the luxury of discussion, multiple experiences and qualifications to draw from, the sole incident controller is only resourced by their own knowledge and experiences. This realisation supports the notion that pre-event risk analysis may be critical to supporting correct decisions during dynamic emergency incidents.

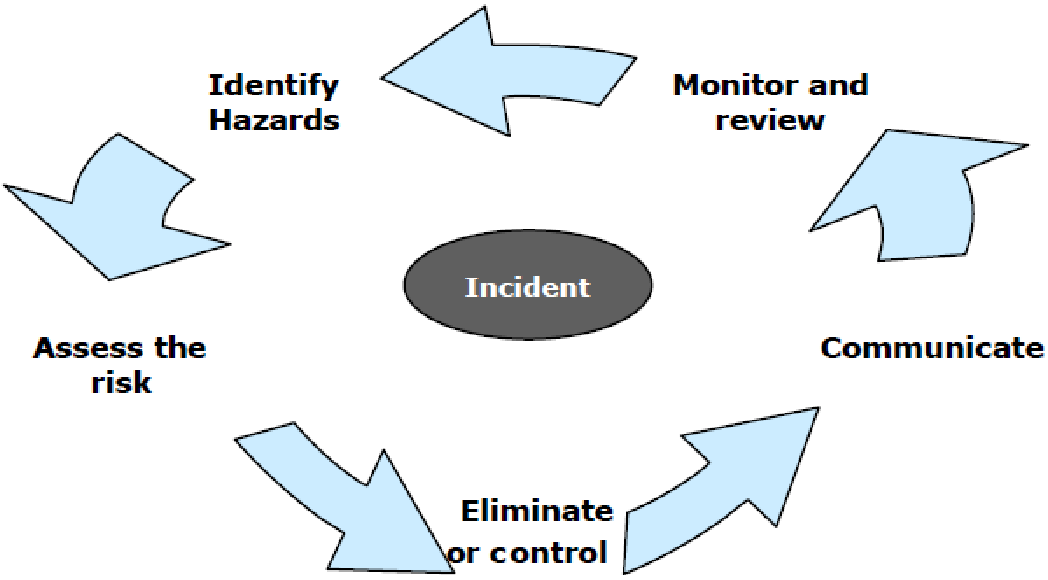

Figure 4: Fireground decision making cycle (Bailey, 2007, p4).

External to the immediate dynamic emergency event, post incident reviews, Worksafe investigations and even criminal prosecutions may occur. These external reviews will occur weeks if not many months after an incident has finished with findings potentially handed down by persons external to the fire service culture. Therefore, critical assessment of the decisions made, particularly if catastrophic outcomes are realised, will not be made against internal fire services procedures or doctrine but rather against the standards and duty of care required by the greater community.

In considering the impacts of both internal and external reviews of risk management during dynamic emergency operations, it is concluded that it is vital for decisions made within the internal firefighting context (during an active dynamic emergency environment) to meet the standards expected by the external community. Failure to achieve this may result in additional consequences unforeseen during the emergency.

2.4 United Kingdom Incident Risk Management

The risk management methodology for dynamic emergency incidents adopted by United Kingdom Fire Services as published by the Department for Communities and Local Government (DCLG) is comprehensive and requires specific attention in this report. The first of these publications is the Fire and Rescue Authorities "Health, safety and welfare framework for the operational environment" (DCLG, 2013) which details a comprehensive architecture for management of dynamic incident risk that commences with the brigade's senior officers and ends with the individual emergency responder on the incident ground. This publication is unique amongst the literature reviewed in that it not only acknowledges Health and Safety legislation, often viewed as encumbrance to emergency response, but embraces it as a pillar of dynamic emergency risk management.

In doing so the United Kingdom Fire Services succinctly define both internal and external organisational risk contexts as they apply to frontline operations allowing incident controllers. Further, DCLG (2013) not only articulates the dynamic incident risk assessment process through the hierarchy of command but provides multiple fire service specific examples for incident controllers and front line personnel of all ranks and operational roles to reference. Perhaps most importantly from an organisational context is the recognition that "standard operational procedures need to be sufficiently flexible to allow the Incident Commander to exercise discretion on the resources and the procedures required to resolve the emergency" (DCLG, 2013, p23). The flexibility for incident controllers and personnel to use 'operational discretion' is carefully articulated and "should be based on a balance in terms of risk versus benefit, and the Incident Commander knowing the action which they are normally required by the relevant standard operational procedure" (DCLG, 2013, p23).

The second publication is the Fire and Rescue Manual 2nd Volume "Fire Service Operations – Incident Command" (DCLG, 2008). It is the doctrine of fire service dynamic incident management at all levels and embraces incident risk management as one of the three key elements required for effective incident command. Most significantly DCLG (2008, p64) recognises "in order to provide an acceptable level of protection at operational incidents, the organisations health and safety management must operate at three different levels – Strategic, Systematic and Dynamic." At a strategic level, risk management defines the fire service's risk attitudes and establishes internal context whilst complying with relevant external contexts. This is achieved through appropriate policy and doctrine that embrace the risk philosophy of the fire service. Systematic risk management is completed by the operational subject matter experts in each discipline. The results subsequently guide the development and implementation of operations including but not limited to safe work systems, procedures, equipment, training and supervision. Dynamic risk management occurs during an operational incident and encompasses all risk management carried out by all personnel involved in the incident whilst an emergency situation is present.

In considering the application of 'dynamic risk management' it is essential to distinguish between time critical emergency situations, for instance where lives are endangered and rescue is required, and non-emergency situations such as body recovery. The distinction is critical as risk thresholds will vary accordingly as demonstrated in the New Zealand "Safe Person Concept" (NZFS, 2008) and the philosophy of the DCLG (2008, p65)

> "*In a highly calculated way, firefighters:*
>
> - *Will take some risk to save saveable lives.*
> - *May take some risk to save saveable property.*

- *Will not take any risk at all to try and save lives or property that are already lost."*

Whilst New Zealand literature considers dynamic incident risk management in isolation, the United Kingdom acknowledges it as only a part of the greater risk management process applicable to the fire service as a workplace and subsequently ensures transference of the internal and external risk contexts into the dynamic incident risk management process. This holistic approach adopted by DCLG (2008, 2013) enables Incident Controllers to manage risk in accordance with AS31000 regardless of the nature of the emergency encountered.

2.5 Discussion

Fire services have a strong culture and tradition that culminates in a unique internal risk management environment. Firefighters have been found to hold common attitudes towards personal risk tolerance and an occupation that places them directly in stressful emergency situations that may promote risk taking behaviour. This is compounded by a perception of community expectation that firefighters will put their own lives in peril for others in life or death situations. Therefore, the requirement for accurate and timely risk assessment and management in dynamic situations becomes critical.

Australian and international fire service literature extensively details the strategic and tactical approaches for a significant variety of dynamic emergency incidents. Significant studies examining the decision making process of incident ground incident controllers were also found. With the exception of DCLG (2008, 2013) the reviewed literature provides somewhat more limited guidance as to the management of risk in dynamic emergency situations. Even more

limited is an analysis of the specific compliance of this guidance with the standards of the external environment and potential external review.

The absence of formal guidance from Australian fire services towards AS31000 compliant risk management is not perceived as a deliberate measure, but rather as the result of an evolution of risk management in business driving standards and litigation at a faster rate than within the unique and largely traditional firefighting environment. It is not suggested that quantitative risk analysis can be undertaken within the dynamic emergency context. However, completion of quantitative risk analysis prior to an event and its use to support risk management practices during dynamic emergency incidents is however, viewed as being critical for the alignment of internal and external expectations and risk management standards.

The philosophies and processes articulated in DCLG (2008, 2013) are the gold standard of dynamic incident risk management. Results of the data obtained and discussed in the next section of this thesis are designed to enable the contextualisation of these documents within the Department of Fire and Emergency Services and to facilitate bridging the risk management knowledge gap identified in Australia.

3.0 Study Methodology

3.1 Overview

The study utilised both qualitative and quantitative research methodologies. Data was collected in two distinct phases. The first involved qualitative observational ethnology, the second involved collection of historical incident and safety reports. Ethics approval was obtained through the Human Ethics Committee, Edith Cowan University whilst formal approval of the research was also provided by the Commissioner of Fire and Emergency Services.

The primary objective of this study was to determine whether current risk management practices in dynamic emergency incidents are compliant with AS31000. A subsequent objective was to define the internal context of dynamic risk management within the operational incident management and response section of the Department of Fire and Emergency Service (DFES). The internal context was defined by either the formal documentation of the organisation (SAHB 436), or in the absence of such documentation, the collective beliefs that serve to form the operating consensus. As the literature review identified an absence of formal documentation or guidance that established the internal context, the first phase of this study utilised ethnographic qualitative research to document the beliefs and dynamic risk management culture of incident controllers within DFES.

The absence of research in the field of rescue science equates to a lack of priors and little guidance regarding study design. The dynamic and irregular nature of emergency operations (DFES, 2012a, 2013a, 2015a, 2015b) resulted in field observation being considered inappropriate by the study team. Further, it was deemed critical to ensure the design of the

study was not only appropriate to answer the research question posed; but would also yield sufficient data to ensure the validity of results. These limitations are addressed through careful study design.

The use of a semi-structured interview and subsequent in-depth structured survey enabled exploration and documentation of the beliefs, understanding and attitudes of a specific population of incident controllers within DFES which ultimately form the internal context of the risk management process (Silverman, 2011; Taylor, 2005). Using this approach, information rich data was collected from the target population.

The limited availability of quantitative data was addressed through the use of Bayesian theorem. In contrast to the traditional frequentist approach, Bayesian statistics provide robust analysis with small data sets (Cutcliffe, Schmidt, Lucas & Bass, 2012; Salkind, 2010). Posterior probability is established through repeated use of Bayesian theorem on empirical data collected during the experiment itself (Wong, Warren & Kawchuk, 2010). In this manner Bayesian analysis is better suited to guide decisions within the context of practical dynamic emergency operations (Ferson, unknown; Goldstein, 2006).

3.2 Phase One

3.2.1 Data Collection

Phase one involved ethnographic qualitative interactive observation of 20 serving officers of the Department of Fire and Emergency Services (DFES) between September 2014 and November 2014. Semi-structured interviews and subsequent in-depth structured surveys were

conducted focusing on the participant's risk attitudes and beliefs. The participation of one candidate was interrupted by an incident call out, resulting in 19 interviews and surveys being available for analysis.

O'Brien (2002) identifies that the number of participants should be guided by the richness of the data. Given the relatively limited population of incident controllers within the DFES Fire & Rescue Service of 274 officers (DFES Human Services, 2016) and the richness of the data collected, the 19 participants representing 7% of the overall population was considered sufficient for the study.

3.2.2 Data Analysis

Data from interviews was analysed using customised Excel spreadsheets created by the lead researcher to establish similar trends related to the understanding of risk and risk management in dynamic situations in order to establish organisational context. Results assisted to establish the internal context of emergency services in relation to dynamic risk management. Bayesian analysis was used to quantify risk acceptance thresholds which further established risk thresholds of the participants.

In this manner, the overall probability of specific outcomes can be determined using the formula:

$$P(A \cap B) = P(A) \times P(B)$$

Where

$P(A \cap B)$ is the probability that both A and B occur;

$P(A)$ is the probability that A will occur; and

$P(B)$ is the probability that B will occur.

The conditional probability (P) of a specific injury being sustained (A) given an injury is sustained during a certain task at an incident (B) can be determined using the formula:

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

Where

$P(A|B)$ is the probability that A will occur given the fact that B has already occurred;

$P(A \cap B)$ is the probability that both A and B occur; and

$P(B)$ is the probability that B will occur.

In order to determine risk tolerance where certainty is not achieved a certainty factor (Blamey, 2008; Lucas, 2008; Roventa & Spircu, 2009) was applied. Using an approach derived from Roventa and Spircu (2009) in consideration of the responses of the entire study population to the semi-structure interview the following certainty factor was developed for the analysis:

$$If\ P(A) \geq 1.5 \times P(B)\ then\ P(A)\ prevails\ with\ limited\ certainty$$

$$If\ P(B) \geq 1.5 \times P(A)\ then\ P(B)\ prevails\ with\ limited\ certainty$$

$$If\ P(A) < 1.5 \times P(B)\ or\ if\ P(B) < 1.5 \times P(A) then\ result\ is\ inconclusive$$

3.3 Phase Two

3.3.1 Data Collection

The objective of phase two of this study was to interrogate existing data sets to establish conditional probabilities that would enhance the understanding of the internal and external context of dynamic risk management within the operational incident management and response section of DFES. Thus a retrospective analysis of safety and incident reports from the DFES Health and Safety data base between January 1st 2001 and January 1st 2015 was conducted. All reports related to incidents responded to by the frontline operational arm of DFES. All information that could identify personnel was redacted by DFES prior to collection by the investigator. 1,997 individual reports were initially analysed. To ensure data reflected injuries sustained during operational events, the following inclusion criterion were applied:

1. Event must relate to a specific operational incident; and
2. An injury must have occurred or the potential for injury must be identified.

For the purposes of this study injury was defined as any adverse outcome that was physical or psychological in nature, whilst the term operational incident was defined as an incident responded to by DFES personnel that was assigned an internal incident identification number. Following application of the inclusion criteria 666 reports were identified as suitable for analysis.

3.3.2 Data Analysis

Data was initially categorised according to:

1. Activity (being the primary task undertaken at the time of the reported incident);

2. Initiating event (being the risk source);
3. Nature of the injury reported;
4. Actual severity of the consequence reported; and
5. Potential severity of the consequence reported.

Based on the report descriptions and the findings of the literature review, 12 categories of activity were determined:

1. Breathing Apparatus – where the use of self-contained breathing apparatus was reported as the primary activity being undertaken;
2. Bushfire Fighting – including grass, scrub and forest firefighting efforts;
3. DBA – Direct Brigade Alarm response to monitored premises fire alarms;
4. Driving – driving of appliances either to or during an emergency incident;
5. Environmental – animal related reports including rescues, bites and stings;
6. Firefighting – all structural and property fire including vehicles but not including reported hazardous materials;
7. Hazmat – Hazardous Materials response;
8. Not Reported – reports that did not identify the activity undertaken at the time of event;
9. RCR – Road Crash Rescue response to vehicle extrication of all types;
10. Rescue – Rescue of all types not involving vehicle extrication;
11. Storm – storm response; and
12. Suicide Response – response to suicide.

Based on the report descriptions 22 initiating events or risk sources were determined:

1. Animal – all animals other than humans;

2. Blast/Explosion – an explosion from any source;
3. Communications – communications procedures related to the incident;
4. Electrical – electrocution, electric shock or other electricity related incident;
5. Entrapment – entrapment of person not attributed to other cause;
6. Environmental – natural events or sources not related to animals;
7. Equipment failure – failure of a specified piece of equipment;
8. Exposure (asbestos) – exposure to asbestos particles;
9. Exposure (biohazard) – exposure to body fluids;
10. Exposure (chemical) – exposure to a chemical not otherwise classified;
11. Exposure (hazmat fire) – exposure to chemicals that are actively involved in fire;
12. Exposure (noise) – exposure to loud noise;
13. Exposure (psychological) – exposure to events reported to (or have the potential to) cause negative psychological impacts;
14. Exposure (smoke) – exposure to smoke and other unburned products of combustion not including hazmat fire;
15. Impact – physical impact of one object on another, typically involving the person reporting;
16. Impaired vision – visual impairment;
17. Not reported – no risk source reported;
18. Operator error – an unintentional or intentional action by a person that resulted in the injury;
19. Other person – injury or event initiated by another person not relating to violence;
20. Physical strain – muscular or joint strain from operational response efforts;
21. Thermal – extreme heat or cold;

22. Violence – physical assault by another person.

Based on the report descriptions 30 categories of injuries were determined:

1. Abdominal – injuries to the abdominal region;
2. Absorption – absorption through the skin or mucous membranes;
3. Ankle – injuries to the ankle;
4. Arm – injuries to the arm not otherwise classified;
5. Back – injuries to the back that were not skeletal in nature, not including neck injuries;
6. Chest – injuries to the chest region;
7. Ear – injuries to one or both ears;
8. Elbow – injuries to the elbow;
9. Eye – injuries to one or both eyes;
10. Face – facial injuries not including the head, neck, eyes or ears;
11. Finger – injuries to one or multiple fingers;
12. Foot – injuries to one or both feet;
13. General – exposures to a substance not otherwise defined in the reports;
14. Groin – injuries to the groin region;
15. Hand – injuries to one or both hands;
16. Head/Spinal – injuries to the head or spine that do or have the potential to cause structural skeletal damage;
17. Heat illness – all forms of heat illness;
18. Hip – injuries to one or both hips;
19. Ingestion – swallowing of a substance;
20. Inhalation – inhalation of a substance;

21. Knee – injuries to one or both knees;
22. Leg – injuries to one or both legs not otherwise classified;
23. Multiple – multiple areas of injury;
24. Neck – neck injury not related to structural damage of the spine;
25. Nil – no injury suffered;
26. Not reported – no injury or exposure reported;
27. Psychological – exposure to events reported to (or have the potential to) cause negative psychological impacts;
28. Shoulder – injuries to one or both shoulders;
29. Thermal – burns as a result from heat or cold; and
30. Wrist – injuries to one or both wrists.

The severity of the consequence was extrapolated from the report description and classified according to the DFES Risk Matrix (DFES, 2015g):

1. Insignificant – no treatment required; no lost time;
2. Minor – first aid treatment only; no lost time;
3. Moderate – medical treatment; lost time – less than 10 days lost;
4. Major – hospitalisation/significant injury; lost time – more than 10 days lost; and
5. Catastrophic – severe permanent injury / disability / fatality(ies).

The potential severity of the consequence was determined by selecting the highest consequence from both the reports collected and review of comparative incident reports from FEMA (2012). The same categories of consequence were applied as above.

The activity at the time of injury and nature of the injury sustained was extrapolated from the incident reports to facilitate probability modelling; determination of severity of the actual and potential consequence; and calculation of incident likelihood. Likelihood was determined using the formula:

$$Occurrence\ per\ year = \frac{Number\ of\ reported\ events}{Period\ of\ reporting\ (15\ years)}$$

Likelihood was defined in accordance with the DFES Risk Matrix (DFES, 2015g):

1. Rare – may only occur in exceptional circumstances (once in 10 years);
2. Unlikely – could occur at some time (once in 5 years);
3. Moderate – should occur sometime (once in 2 years);
4. Likely – will probably occur in most circumstances (at least once per year); and
5. Very likely – expected to occur in most circumstances (more than once per year).

Data relating to the type of activity undertaken at the time of injury and the nature of the injury sustained was analysed using Bayesian statistics to determine the overall and conditional probability of specific injuries being sustained during the various tasks undertaken during an emergency incident.

The analysis was repeated for each activity, risk source and injury to determine the conditional probability of:

1. A specific injury being sustained (A) given an injury is sustained during a certain task at an incident (B);
2. A certain consequence severity occurring based on historical data (A) given an injury is sustained during a certain task at an incident (B); and

3. A certain potential consequence was possible (A) given an injury sustained during a certain task at an incident.

3.3.3 Limitations

One limitation of the study was potential reluctance of participants to provide answers, beliefs or attitudes that they felt may not be viewed favourably by superior officers. Reluctance to participate within this study on the grounds was addressed through a reassurance of the anonymity of all data collected. Despite this reassurance, some potential participants elected not to participate. This may have resulted in some bias when defining the internal context of the organisation.

During the initial stages of development of the study proposal a concern was raised that due to the relatively small size of the operational service of DFES; factors such as age, rank and gender could be used to identify participants. Therefore, participants age, rank and gender were not recorded to ensure the anonymity which subsequently limited the potential for data analysis on these characteristics.

Another limitation was the limited injury priors available for analysis. The accuracy of documentation, potential reluctance of frontline staff to report incidents and limited information documented in recorded incidents may lead to bias in calculated probabilities. A benefit of the use of Bayesian analysis was that future studies can build upon these initial findings to enhance the accuracy of calculated probabilities as more data become available.

Only a single emergency service within Western Australia was examined in this study. The internal contexts between different emergency services within the same state and the same emergency service in different states will inevitably vary to some degree. The results of this study are directly applicable to dynamic risk management in emergency incidents within the DFES in Western Australia, but do not necessarily represent the internal contexts of other emergency services.

4.0 Results and Discussion

This chapter discusses the profile of participants in phase 1 of the study. Results and analysis of the respondents' interview questions and structured survey are reported upon. The results and analysis of the 666 incident reports included in phase 2 of the study are also detailed in this chapter.

4.1 Phase One

4.1.1 Introduction

The objective of this study was to define the internal and external context of dynamic risk management within the operational incident management and response section of the Department of Fire and Emergency Service (DFES). The semi-structured interview was specifically designed to extrapolate and document the participant's understanding and attitudes towards 'traditional' and dynamic risk management.

Subsequently four questions were asked during the interview:

1. How do you define risk?
2. How do you manage risk in a dynamic emergency environment compared to other situations and contexts?
3. How do you decide whether risks are acceptable in a dynamic emergency environment?
4. Does the risk management process differ in the dynamic emergency environment compared to other situations? If yes, then how?

4.1.2 Profile of participants

The profile of participants was collected from questions within the structured survey. The 19 participants were all operational incident controllers at various ranks within DFES. Both

metropolitan and regional staff were included in the study. Table 1 shows the number of years' experience of the participants:

Experience	Number	Percent
Nil	0	0%
0-5	0	0%
6-10	1	5%
11-15	5	26%
16-20	2	11%
21-25	3	16%
25+	7	37%
Other	1	5%

Table 1: Comparison of years' experience of participants

As shown in Table 1, no respondents had less than six years' experience. This was not unexpected due to entry level officers requiring a minimum Senior Firefighter qualification prior to application which takes five years to obtain. By a fractional margin the majority of participants held in excess of 20 years' experience (53%). Without further research there appears to be no specific reason for this. The participant whom selected "other" did not provide further elaboration.

The second comparison focused upon the basis of the highest level of training or education the participant had received in AS31000.

Answer	Number	Percent
None	3	17%
Short Course	1	6%
In House	12	67%
Undergraduate	0	0%
Postgraduate	1	6%
Other	1	6%

Table 2: Comparison of training in AS31000

The results overwhelmingly illustrate the majority of participants believed they had received "In House" training in the AS31000 risk management process. The participant who marked "Other" provided clarification that risk management had been discussed as a component of other courses but had not been specifically addressed in its own right. One participant did not provide an answer to the question. These results support the findings of Penney (2013) whereby professional craft knowledge was considered to be passed down through generations of firefighters as opposed to being formally studied through external providers. The results also appear to support the initial conclusions of the literature review that emergency services may have developed risk management attitudes and beliefs that are internally valid (Ash & Smallman, 2010; Fender, 2003; Jacobs, 2010; Lofflin & Kipp, 1997), but are not necessarily compliant with AS31000 which requires internal context to be explicitly defined. Such attitudes may prevail in an apparently successful manner whilst they remain unchallenged, however should they be examined in detail by an external party it is foreseeable that the practices would face at least some level of criticism. The level of criticism would likely be

significant should the internal risk attitudes be found to both be inconsistent with AS31000 and contribute towards the injury or death of emergency services personnel.

The third comparison focused upon the basis of the highest level of training or education the participant had received in Dynamic Risk Management.

Answer	Number	Percent
None	4	21%
Short Course	2	11%
In House	12	63%
Undergraduate	0	0%
Postgraduate	0	0%
Other	1	5%

Table 3: Comparison of training in Dynamic Risk Management

The participant who marked "Other" provided clarification they had received "In House" training in Dynamic Risk Management. These findings are consistent with those in Table 2 and appear consistent with the literature which did not report any tertiary risk management training (Ash & Smallman, 2010; Fender, 2003; Lofflin & Kipp, 1997) undertaken by personnel in other fire services.

Participants were also questioned as to whether they had been injured at an emergency incident being controlled by another person. These results are shown in Table 4.

Answer	Number	Percent
Yes	9	47%
No	10	53%

Table 4: Comparison of participants injured at an incident controlled by other person.

These results indicate an almost even distribution of those participants who had and had not been injured at incidents controlled by other parties. As a result of these findings the structured survey was subject to additional analysis to determine whether being injured under another person's command resulted in certain bias. This additional analysis is discussed in Chapter 5.

The fifth comparison focused upon the basis of whether participants had been responsible for managing risk at an emergency incident where another responder had been severely injured.

Answer	Number	Percent
Yes	0	0%
No	19	100%

Table 5: Comparison of participants had been responsible for managing risk at an incident where another person was severely injured.

As reported in Table 5, all participants identified they had never been responsible for managing risk at an incident where another person was severely injured. Further investigation, beyond the scope of this study would be required to determine whether answers to this question were

accurate or skewed as a result of participants not wanting to admit to a person being injured at an incident they were responsible for managing due to fears of potential professional ramifications.

The final comparison focused upon the participants' perception regarding their own level of expertise in risk management specific to emergency services response. These results are detailed in Table 6.

Answer	Number	Percent
Cannot effectively manage risk	0	0%
Can effectively manage risk in limited emergency services contexts	1	5%
Can effectively manage risk in most emergency services contexts	14	74%
Can effectively manage risk in every emergency services context	4	21%
Excel at managing risk in all emergency services contexts	0	0%
Other	0	0%

Table 6: Comparison of participants' perception of risk management expertise.

These results demonstrate an overwhelming majority of participants perceive they could personally effectively manage risk in most emergency services contexts. This was not unexpected as DFES is identified as an "all hazards agency" (DFES, 2013c, 2015c, 2015f). The results also suggest that participants collectively believe they can effectively manage risk

in various emergency service contexts regardless of the level of training they have received in AS31000. In stark contradiction to SAHB 436:2013 these results suggest an internal attitude that AS31000 is not necessarily required for effective risk management in dynamic emergency contexts. This conclusion is consistent with the reported beliefs of personnel in international fire services (Ash and Smallman, 2010; Jacobs, 2010) suggesting that for risk management to be compliant with AS31000 it must be ingrained as part of the core culture of the fire service.

4.1.3 Semi-structured Interviews

The first question asked of participants in the semi-structured interview was "*How do you define risk?*" AS31000 (s2.1) defines the term "Risk" as the "effect of uncertainty on objectives." Further notes are provided in AS31000 (s2.1) as:

1. An effect is a deviation from the expected – positive and/or negative;
2. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organisation wide, project, product and process);
3. Risk is often characterised by reference to potential events and consequences or a combination of these;
4. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence; and
5. Uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood.

Whilst all participants responses included at least part of the associated factors identified in the notes of AS31000 (s2.1) that risk is a consideration of consequences and likelihood, only one

participant (5%) provided the answer "*it is the effect of uncertainty on objectives*." Five participants (26%) provided answers that were specific to emergency response without consideration of the greater application of risk and one participant provided the restrictive definition "*risk is the potential to injure me*." Consistent with the findings of Tissington (2004) these answers suggest participants generally have a perception of risk as the practical consideration of consequence and likelihood as it applies to a reactive emergency environment as opposed to a considered and managed process. This understanding of risk is not absolutely unique to the study group, with similar definitions reported by Reinhardt-Klein (2010) but is different to that of at least one other emergency service in Australia (ACTESA, unknown). This suggests the study group have adopted a definition of risk that is reasonably consistent throughout their population and contextualised to their perception of reality but does not consider all elements detailed in AS31000.

The second question asked of participants was "*How do you manage risk in a dynamic emergency environment compared to other situations and contexts?*" In response, nearly all participants identified that risk management in dynamic contexts was based on a similar process to risk management in other situations but with limited information available and with restricted time frames in which to make decisions. Two participants (10%) expressed the opinion that dynamic risk management required more "forward thinking" than risk management in other situations. These responses again suggest the study group have adopted a definition of risk that is reasonably consistent throughout their population and contextualised to their perception of reality but does not consider all elements detailed in AS31000, especially when consideration is given to the example of the special forces soldier in a hostage situation detailed in SAHB436 (p45).

Eleven participants (58%) also expressed that they managed risk in dynamic emergency environments according to how they believed their organisation expected them to do so or that they managed risk in accordance with organisational procedures and protocols. This suggests the majority of participants believed they managed risk using the same risk attitudes as their organisation, a notion that is analysed further in chapter 5 with consideration that the literature review found an absence of documented organisational risk thresholds and attitudes.

Responses from the study group to the third question "*How do you decide whether risks are acceptable in a dynamic emergency environment?*" were varied. Five participants (26%) reported they relied on organisational procedures and protocols; nine participants (47%) reported they relied on personal prior experience to determine whether risks were acceptable; three (16%) participants stated they simply relied on whether they believed the risk was acceptable to themselves personally; and two (10%) participants responded that in the case of "life involvement" (being the fire services terminology for when potential consequences include the loss of occupant life) then all risks are acceptable.

Variation in answers provided represents significant variance in the risk thresholds between incident controllers within the same organisation. Conflicts between risk attitudes will foreseeably lead to increased risk at an emergency incident as additional uncertainty is introduced when individuals work together to form Incident Management Teams or are responsible for different sectors within the same emergency incident. When considered in conjunction with the answers provided to question two, the variance in risk thresholds between participants suggests an absence of a defined organisational internal risk context that may

otherwise guide participants towards similar answers. This notion is consistent with the literature (ACTESA, date unknown; Fender, 2003) and reinforces the conclusion that for risk management to be compliant with AS31000 it must be ingrained as part of the core culture of the fire service inclusive of explicitly defined risk tolerances. These findings are explored more in the discussion of the results of the structured survey.

The final question posed to participants was "*Does the risk management process differ in the dynamic emergency environment compared to other situations? If yes, then how?*" Responses provided by participants were far less varied in this instance. Eight participants (42%) stated there was no difference in the process, however four of those eight participants also stated the time frame available for completing the risk assessment was significantly reduced during dynamic emergency environments. Interestingly, of those eight participants one also stated that risk tolerance is significantly higher during dynamic emergency operations compared to other situations which suggests fluctuating risk thresholds depending on the participant's evolving perception of the severity of an incident. Only one participant (5%) identified that the risk management process had to be repeated multiple times throughout the emergency incident, suggesting the remaining participants did not consider repeated risk application of the risk management process necessary. This is in contradiction to SAHB 436:2013.

Ten participants (53%) stated that the risk management process did differ in the dynamic emergency environment compared to other situations. Those participants all identified that the process changed due to the significant reduction in both available information on which to make decisions and available time to gather further information. One of the ten participants

clarified they felt *"pushed to do things you wouldn't normally do due to expectations and pressure"* indicating they operated at risk thresholds they personally felt were unacceptable.

Of all 19 participants only one (5%) stated the dynamic risk management process was reactive as opposed to being a thought out process. These findings appear to contradict the previous findings of Ash and Smallman (2010), Fender (2003) and Naikar (2010) all of whom identified decision making during dynamic emergency incidents is reactive and based on recognition of specific cues. Whilst this finding must be interpreted with some caution due to the relatively small sample size of this study, it is supported by the answers provided by the study group to the second question posed in the interview. Subsequently, this suggests that risk management in dynamic emergency situations within the study population may be more aligned to AS31000 than other selected fire services.

One participant (5%) stated they were unsure whether the risk management process differed in the dynamic emergency environment compared to other situations.

4.1.4 Structured Survey

The first question in the structured survey required participants to identify the severity of various potential consequences. From the answers provided, probability analysis was completed across the entire sample population. Conditional probability was then calculated on the basis that participants had or had not been previously injured at an incident (from the results reported in Table 4). These results were compared to the severity assigned to the consequence in the DFES Risk Matrix (2015g) shown in Table 7. In this table the highest probability for

the entire study population (represented in the “All” column) is highlighted in blue; the highest conditional probability of the previously injured group (represented in the “Injured” column) is highlighted in orange; the highest conditional probability of the group never having been injured (represented in the “Never” column) is highlighted in green; and the severity assigned in accordance with the DFES Risk Matrix (DFES, 2015g) outlined in red.

Analysis of the results revealed there is a conditional probability of 0.00 (zero) for all participants assigning the same severity to a consequence given the event being realised. Only in a single instance a subgroup completely agreed on the severity of a consequence, being the non-injured group agreeing that the death of a rescuer was of catastrophic severity (represented by a conditional probability of 1.00).

Further analysis of Table 7 revealed there was an equal probability between the group that had never been injured, a conditional probability of 0.2 that the survey groups’ majority severity perception would align with the severity assigned using the DFES Risk Matrix (2015g). Whilst some variance was expected by the lead researcher due to potential differences in individuals’ perception of the consequence realised, the conditional probability of 0.2 signifies agreement between participants and DFES in the perception of consequence severity of only a single occurrence each year (refer to the analysis of consequence likelihood on page 41 for calculation details). It is therefore concluded that internal context of risk attitudes is not harmonious amongst the study group and may lead to conflicting risk management during dynamic emergency situations or post incident analysis.

Descriptive analysis of the results illustrated in Table 7 provide a mean probability of 0.612 (standard deviation of 0.142) that the entire survey group will agree on the severity of any given consequence. This further supports the findings of the potential for conflicting risk attitudes between incident controllers and parties conducting post incident analysis.

Rating	Insignificant			Minor			Moderate			Major			Catastrophic		
Consequence	All	Injured	Never	All	Injured	Never	All	Injured	Never	All	Injured	Never	All	Injured	Never
Near miss - cut finger	0.42	0.44	0.40	0.53	0.44	0.60	0.05	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Near miss - broken arm	0.05	0.00	0.10	0.21	0.22	0.20	0.58	0.56	0.60	0.16	0.22	0.10	0.00	0.00	0.00
Near miss - death of rescuer	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.20	0.42	0.44	0.40	0.47	0.56	0.40
Near miss - exposure to acutely toxic material	0.00	0.00	0.00	0.05	0.00	0.10	0.11	0.00	0.20	0.63	0.78	0.50	0.21	0.22	0.20
Near miss - exposure to hazardous material with health effects that may take 20 years to occur	0.00	0.00	0.00	0.05	0.00	0.10	0.26	0.00	0.50	0.47	0.78	0.20	0.21	0.22	0.20
Scratch or dent to a vehicle	0.26	0.22	0.30	0.68	0.67	0.70	0.05	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cut finger requiring first aid treatment	0.11	0.00	0.20	0.83	0.88	0.80	0.06	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Broken arm requiring hospitalisation	0.00	0.00	0.00	0.11	0.00	0.20	0.68	0.67	0.70	0.21	0.33	0.10	0.00	0.00	0.00
Death of a rescuer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.95	0.89	1.00
Exposure to acutely toxic hazardous material requiring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.56	0.70	0.37	0.44	0.30

hospital admission															
Exposure to hazardous material that results in lung damage only evident 20 years post exposure	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.20	0.42	0.44	0.40	0.47	0.56	0.40
Inhaling asbestos particulates and dust as a result of rescue activities	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.10	0.61	0.67	0.50	0.33	0.33	0.40
Exposure to silica particulates and dust as a result of rescue activities	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.11	0.40	0.63	0.78	0.60	0.11	0.11	0.00
Exposure to glass particulates and dusts as a result of rescue activities	0.00	0.00	0.00	0.06	0.00	0.11	0.17	0.11	0.22	0.72	0.78	0.67	0.06	0.11	0.00
Damage to a vehicle resulting in $1000 damage	0.05	0.00	0.10	0.79	0.89	0.70	0.16	0.11	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Damage to a vehicle resulting in $20,000 damage	0.00	0.00	0.00	0.42	0.44	0.40	0.42	0.56	0.30	0.16	0.00	0.30	0.00	0.00	0.00
Damage to the environment that does not result in long term impact	0.05	0.00	0.10	0.68	0.44	0.90	0.26	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Damage to the environment resulting in long term impact	0.00	0.00	0.00	0.05	0.00	0.10	0.42	0.33	0.50	0.37	0.44	0.30	0.16	0.22	0.10
Lung tissue damage without respiratory impairment	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.22	0.50	0.58	0.78	0.40	0.05	0.00	0.10

Lung tissue damage that limits physical activity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.44	0.60	0.47	0.56	0.40

Table 7: Perceptions of consequence severity.

An individual's beliefs and expectations can significantly affect the internal context of the risk management process (SAHB 436:2013). To investigate how this may be a factor in risk management during dynamic emergency operations, the second question of the survey required participants to identify their beliefs regarding external and personal risk attitudes and expectations using a Likert scale. These results are detailed in Table 8 as a percentage of the study population. In this table the highest percentage for the entire study population (represented in the "All" column) is highlighted in blue; the highest percentage of the previously injured group (represented in the "Injured" column) is highlighted in orange; and the highest percentage of the group never having been injured (represented in the "Never" column) is highlighted ingreen.

Belief	**Strongly Disagree (%)**			**Disagree (%)**			**Neutral (%)**			**Agree (%)**			**Strongly Agree (%)**		
Participant Group	**All**	**Injured**	**Never**	**All**	**Injured**	**Never**	**All**	**Injured**	**Never**	**All**	**Injured**	**Never**	**All**	**Injured**	**Never**
There is an expectation that emergency services personnel will risk their own lives to save others	11	11	10	11	0	20	5	11	0	53	44	60	21	33	10
There is an expectation that emergency	16	11	20	11	0	20	21	11	30	47	67	30	5	11	0

services personnel will risk their own lives to save property															
There is an expectation that emergency services personnel will risk their own lives to save the environment	21	11	30	16	11	20	37	56	20	26	22	30	0	0	0
Emergency services personnel have a moral obligation to put themselves at a higher level of risk than the general public in the course of their duties	5	0	10	16	11	20	5	11	0	68	67	70	5	11	0

Table 8: Participant beliefs.

Analysis of these results reveals that the overwhelming majority of the entire study group (74%), as well as the both subgroups (Injured 77% and Never Injured 70%), believed there were external expectations that emergency services personnel would risk their own lives to save others. By comparison only 52% of the entire study group (Injured 78% and Never Injured 30%) believed there were external expectations that emergency services personnel would risk their own lives to save property. This difference in attitudes between the Injured and Never Injured populations appears to suggest personnel who had a higher personal risk threshold may be more likely to be injured during emergency operations, however further research is required to confirm this hypothesis.

Analysis of the responses to the statement "*There is an expectation that emergency services personnel will risk their own lives to save the environment*" was less conclusive but appeared to suggest less belief amongst the study group that this was the case (37% of the total study group stating they either disagreed or strongly disagreed with the statement).

In order to further define the risk attitudes and tolerance of the study group, participants were required to identify whether potential scenarios were either acceptable or unacceptable. Participants were first required to answer the question in the context that they were personally exposed to the risk source, the subsequent context was that the participant was responsible for other responders and it was these responders who were exposed to the risk source.

Results are detailed in Table 9, shown as overall probability and subsequent conditional probability based on whether the participant had been previously injured at an emergency incident. Where results were equivalent between the two contexts they are highlighted in the table. For the entire study population (represented in the "All" column) equivalence is highlighted in blue; equivalence amongst the previously injured group (represented in the "Injured" column) is highlighted in orange; and equivalence amongst the group never having been injured (represented in the "Never" column) is highlighted in green. Where the conditional probability of risk acceptance is higher in a given scenario amongst the "Injured" population the cell is outlined in blue; the cell is highlighted in red when the conditional probability of risk acceptance is higher amongst the "Never" population.

Analysis revealed a probability of certainty (where probability equals 1.00) amongst the study group of 0.143, meaning there is a probability of 0.857 that participants did not collectively absolutely agree on risk tolerance attitudes or thresholds. Further analysis revealed a probability of only 0.286 that all participants shared the same risk tolerance across the presented scenarios. This probability increased to 0.381 amongst the "Injured" population whilst there was no change in the probability of agreeance amongst the "Never" population compared to all participants. One potential explanations for the increased consensus of risk acceptance amongst the "Injured" population may be that those participants whom were previously injured held a higher risk tolerance and therefore were more likely to undertake hazardous tasks that may result in injury compared to the "Never" group.

Risk acceptance where the exposure was personal was equal to or higher than the risk acceptance where exposure was to personnel under the participant's command in all scenarios with the exception of "*entering a toxic smoke plume to rescue a person where there is a low or high probability of developing cancer*" where the risk acceptance was nominally lower when the exposure was personal. No justification for this result could be determined with any certainty by the lead researcher and requires additional study. These results suggest a tendency for participants to accept a higher level of risk where the consequences will not extend to other persons.

In order to determine risk tolerance where certainty is not achieved a certainty factor was applied using an approach derived from Roventa and Spircu (2009). Results of this analysis for each scenario are provided in Table 9. When considering risk tolerance with limited certainty

the probability of risk tolerance agreement between personal and personnel exposure increased to from 0.143 to 0.761 across the entire study population.

	Risk to Participant Themselves						Risk to Personnel Under the Command of the Participant					
Risk Tolerance	**Acceptable**			**Unacceptable**			**Acceptable**			**Unacceptable**		
Context and Risk	**ALL**	**INJURED**	**NEVER**	**ALL**	**INJURED**	**NEVER**	**ALL**	**INJURED**	**NEVER**	**ALL**	**INJURED**	**NEVER**
Entering a burning building to rescue a person where there is a low probability of being severely injured or killed.	1.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00
	Acceptable - Certain						Acceptable - Certain					
Entering a burning building to rescue a person where there is a moderate probability of being severely injured or killed.	0.63	0.56	0.70	0.37	0.44	0.30	0.47	0.56	0.40	0.53	0.44	0.60
	Acceptable – limited certainty as 0.65≥1.5x0.37						Inconclusive					
Entering a burning building to rescue a person where there is a high probability of being severely injured or killed.	0.16	0.00	0.30	0.84	1.00	0.70	0.05	0.00	0.10	0.95	1.00	0.90
	Unacceptable – limited certainty as 0.84≥1.5x0.16						Unacceptable – limited certainty as 0.95≥1.5x0.05					
Rescuing a person from a vehicle where there is a low probability of being exposed to dust that may cause immediate lung damage.	0.95	1.00	0.90	0.05	0.00	0.10	0.79	0.89	0.70	0.21	0.11	0.30
	Acceptable – limited certainty as 0.95≥1.5x0.05						Acceptable – limited certainty as 0.79≥1.5x0.21					
Rescuing a person from a vehicle where there is a moderate probability of being exposed to dust that may cause immediate lung damage.	0.47	0.56	0.40	0.53	0.44	0.60	0.32	0.33	0.30	0.68	0.67	0.70
	Inconclusive						Unacceptable – limited certainty as 0.68≥1.5x0.32					
Rescuing a person from a vehicle where there is a high probability of being exposed to dust that may cause immediate lung damage.	0.37	0.33	0.40	0.63	0.67	0.60	0.21	0.22	0.20	0.79	0.78	0.80
	Unacceptable – limited certainty as 0.63≥1.5x0.37						Unacceptable – limited certainty as 0.79≥1.5x021					

Entering a toxic smoke plume to rescue a person where there is a low probability of developing cancer.	0.58	0.56	0.60	0.42	0.44	0.40	0.63	0.78	0.50	0.37	0.22	0.50
	Inconclusive						Acceptable – limited certainty as 0.63≥1.5x0.37					
Entering a toxic smoke plume to rescue a person where there is a moderate probability of developing cancer.	0.26	0.22	0.30	0.74	0.78	0.70	0.26	0.22	0.30	0.74	0.78	0.70
	Unacceptable – limited certainty as 0.74≥1.5x0.26						Unacceptable – limited certainty as 0.74≥1.5x0.26					
Entering a toxic smoke plume to rescue a person where there is a high probability of developing cancer.	0.16	0.11	0.20	0.84	0.89	0.80	0.26	0.22	0.20	0.74	0.78	0.80
	Unacceptable – limited certainty as 0.84≥1.5x0.16						Unacceptable – limited certainty as 0.74≥1.5x0.26					
Rescuing a person from a vehicle where there is a low probability of being exposed to dust that may cause long term lung damage.	0.84	0.89	0.90	0.16	0.11	0.10	0.74	1.00	0.60	0.26	0.00	0.40
	Acceptable – limited certainty as 0.84≥1.5x0.16						Acceptable – limited certainty as 0.74≥1.5x0.26					
Rescuing a person from a vehicle where there is a moderate probability of being exposed to dust that may cause long term lung damage.	0.32	0.22	0.40	0.68	0.78	0.60	0.26	0.22	0.30	0.74	0.78	0.70
	Unacceptable – limited certainty as 0.68≥1.5x0.32						Unacceptable – limited certainty as 0.74≥1.5x0.26					
Rescuing a person from a vehicle where there is a high probability of being exposed to dust that may cause long term lung damage.	0.21	0.22	0.20	0.79	0.78	0.80	0.21	0.22	0.20	0.79	0.78	0.80
	Unacceptable – limited certainty as 0.79≥1.5x0.21						Unacceptable – limited certainty as 0.79≥1.5x0.21					
Entering a burning building to rescue a child where there is a low probability of being severely injured or killed.	1.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00
	Acceptable - Certain						Acceptable - Certain					
Entering a burning building to rescue a child where there is a moderate probability of being severely injured or killed.	0.79	0.67	0.90	0.21	0.33	0.10	0.53	0.67	0.40	0.47	0.33	0.60
	Acceptable – limited certainty as 0.79≥1.5x0.21						Inconclusive					
Entering a burning building to rescue a child where there is a high probability of being severely injured or killed.	0.21	0.11	0.30	0.79	0.89	0.70	0.11	0.11	0.10	0.89	0.89	0.90
	Unacceptable – limited certainty as 0.79≥1.5x0.21						Unacceptable – limited certainty as 0.89≥1.5x0.11					
Entering a burning building to rescue a colleague where there is a low probability of being severely injured or killed.	1.00	1.00	1.00	0.00	0.00	0.00	0.95	1.00	0.90	0.05	0.00	0.10
	Acceptable - Certain						Acceptable – limited certainty as 0.95≥1.5x0.05					

Entering a burning building to rescue a colleague where there is a moderate probability of being severely injured or killed.	0.79	0.67	0.90	0.21	0.33	0.10	Acceptable – limited certainty as 0.79≥1.5x0.21	0.63	0.78	0.50	0.37	0.22	0.50	Acceptable – limited certainty as 0.63≥1.5x0.37
Entering a burning building to rescue a colleague where there is a high probability of being severely injured or killed.	0.37	0.33	0.40	0.63	0.67	0.60	Unacceptable – limited certainty as 0.63≥1.5x0.37	0.16	0.22	0.10	0.84	0.78	0.90	Unacceptable – limited certainty as 0.84≥1.5x0.16
Entering a burning building to save the property where there is a low probability of being severely injured or killed.	0.84	0.78	0.90	0.16	0.22	0.10	Acceptable – limited certainty as 0.84≥1.5x0.16	0.68	0.67	0.70	0.32	0.33	0.30	Acceptable – limited certainty as 0.68≥1.5x0.16
Entering a burning building to save the property where there is a moderate probability of being severely injured or killed.	0.16	0.11	0.20	0.84	0.89	0.80	Unacceptable – limited certainty as 0.84≥1.5x0.16	0.16	0.22	0.10	0.84	0.78	0.90	Unacceptable – limited certainty as 0.84≥1.5x0.16
Entering a burning building to save the property where there is a high probability of being severely injured or killed.	0.00	0.00	0.00	1.00	1.00	1.00	Unacceptable - Certain	0.00	0.00	0.00	1.00	1.00	1.00	Unacceptable - Certain

Table 9: Risk tolerance.

Risk acceptance with limited certainty was also higher for the entire study population and sub populations where life involvement was present. Participants would typically put both their own safety and the safety of personnel under their command at increased risk to facilitate occupant rescue (from all risk sources). This risk acceptance with limited certainty increased marginally where rescue was of a colleague, particularly when risk was transferred from the participant to those under the participant's control. Marginal increase in risk threshold was observed between personal and personnel exposure where rescue involved a child as opposed to an adult. Whilst it is hypothesised this increase may be a result of perceived community expectations (as detailed in Table 8), further investigation is required to confirm this proposition.

Risk acceptance with limited certainty declined quickly for the protection of property, whilst the level of certainty decreased as the lead time to the realisation of potential consequences increased. For example, the certainty regarding risk acceptance involving acute impacts such as trauma was generally higher compared to those involving cancer or lung disease. This suggest participants were more likely to be concerned with impacts they can witness immediately and is supported by the findings of Penney (2013).

Descriptive analysis of the results illustrated in Table 9 provide a mean probability of 0.529 (standard deviation of 0.336) that the entire survey group will agree on the acceptability of any given situation where the risk is personal in nature. By comparison a mean probability of 0.449 (standard deviation of 0.321) that the entire survey group will agree on the acceptability of any given situation where the risk is to personnel under the participant's command. This further supports the findings that participants were more likely to accept risk when they believed the consequences were limited to themselves.

4.1.5 Summary of Findings:

Analysis of the results of phase one can be summarised as:

1. Participants demonstrated limited tendency towards a higher risk threshold than those described in the DGLC (2008, 2013) philosophies when occupant or rescuer life involvement was under threat;
2. Participants overwhelming demonstrated a detailed understanding of hazard mitigation at dynamic emergency incidents through the appropriate use of controls and a

culturalised understanding of risk. However, this understanding did not extend to the definition of risk or risk management process defined in AS31000;

3. Whilst all participants recognised the requirement to continually reassess controls applied to hazards during dynamic emergency incidents, participants did not collectively demonstrate an understanding that the risk management process is a single process that must be repeated at regular intervals as required by the nature of the incident;
4. The majority of participants expressed a belief they were subject to external expectations that emergency personnel would risk their lives to protect other people and had a moral obligation to do so;
5. A lesser majority of participants expressed a belief they were subject to external expectations that emergency personnel would risk their lives to protect property;
6. Significant variance was observed between organisational and participant attitudes regarding consequence severity;
7. In the absence of documented organisational risk thresholds for dynamic emergency incidents, there was limited certainty amongst participants in regards to determining risk acceptance. Further, the level of agreement varied depending on whether the risk was personal in nature or applicable to the personnel under the participant's command;
8. Risk acceptance was the highest during life involvement situations and marginally higher again where the life under threat was either a child or a colleague. Risk acceptance declined quickly where life involvement did not occur; and
9. The level of certainty regarding risk acceptance decreased as the lead time to the realisation of potential consequences increased. For example the certainty regarding

risk acceptance involving acute impacts such as trauma was generally higher compared to those involving cancer or lung disease.

4.2 Phase Two

4.2.1 Introduction

The objective of phase two of the study was to analyse available data to provide enhanced understanding of risk sources during dynamic emergency incidents. This analysis would facilitate enhanced awareness of the internal context of emergency operations by incident controllers as part of the risk management process.

4.2.2 Analysis

Initial analysis enabled the calculation of conditional probability given a reportable incident occurs (B) and likelihood on the basis of activity, risk source and nature of injury reported. The results are detailed in Tables 10-12. Each table is ordered on the basis of frequency.

Activity (A)	Count	P(A|B)	Occurrence per year	Likelihood
Firefighting	327	0.491	21.800	Almost certain
RCR	110	0.165	7.333	Almost certain
Bushfire fighting	99	0.149	6.600	Almost certain
Rescue	36	0.054	2.400	Almost certain
Driving	30	0.045	2.000	Almost certain
Breathing Apparatus	20	0.030	1.333	Almost certain

Suicide Response	15	0.023	1.000	Almost certain
Hazmat	12	0.018	0.800	Moderate
Environmental	8	0.012	0.533	Moderate
DBA	5	0.008	0.333	Moderate
Not reported	2	0.003	0.133	Unlikely
Storm	2	0.003	0.133	Unlikely

Table 10: Analysis by activity.

Risk source (A)	Count	P(A|B)	Occurrence per year	Likelihood
Physical Strain	215	0.323	14.333	Almost certain
Exposure - asbestos	120	0.180	8.000	Almost certain
Exposure - psychological	95	0.143	6.333	Almost certain
Impact	49	0.074	3.267	Almost certain
Exposure - smoke	37	0.056	2.467	Almost certain
Exposure - biohazard	24	0.036	1.600	Almost certain
Exposure - hazmat fire	24	0.036	1.600	Almost certain
Equipment failure	21	0.032	1.400	Almost certain
Exposure - chemical	20	0.030	1.333	Almost certain
Thermal	16	0.024	1.067	Likely
Operator error	11	0.017	0.733	Moderate
Animal	7	0.011	0.467	Moderate
Communications	5	0.008	0.333	Moderate
Environmental	4	0.006	0.267	Moderate
Impaired Vision	4	0.006	0.267	Moderate
Other person	4	0.006	0.267	Moderate

Blast/Explosion	2	0.003	0.133	Unlikely
Entrapment	2	0.003	0.133	Unlikely
Exposure - noise	2	0.003	0.133	Unlikely
Violence	2	0.003	0.133	Unlikely
Electrical	1	0.002	0.067	Rare
Not reported	1	0.002	0.067	Rare

Table 11: Analysis by risk source.

Nature of injury (A)	Count	P(A|B)	Occurrence per year	Likelihood
Inhalation	163	0.245	10.867	Almost certain
Psychological	96	0.144	6.400	Almost certain
Nil	70	0.105	4.667	Almost certain
Back	56	0.084	3.733	Almost certain
Knee	42	0.063	2.800	Almost certain
Eye	32	0.048	2.133	Almost certain
Heat illness	30	0.045	2.000	Almost certain
Shoulder	26	0.039	1.733	Almost certain
Leg	16	0.024	1.067	Almost certain
General	15	0.023	1.000	Likely
Head / spinal	13	0.020	0.867	Likely
Ankle	11	0.017	0.733	Moderate
Arm	11	0.017	0.733	Moderate
Finger	9	0.014	0.600	Moderate
Face	8	0.012	0.533	Moderate
Foot	8	0.012	0.533	Moderate

Multiple	8	0.012	0.533	Moderate
Neck	8	0.012	0.533	Moderate
Hand	7	0.011	0.467	Moderate
Elbow	6	0.009	0.400	Moderate
Ear	5	0.008	0.333	Moderate
Absorption	4	0.006	0.267	Moderate
Not reported	4	0.006	0.267	Moderate
Wrist	4	0.006	0.267	Moderate
Chest	3	0.005	0.200	Unlikely
Groin	3	0.005	0.200	Unlikely
Hip	3	0.005	0.200	Unlikely
Abdominal	2	0.003	0.133	Unlikely
Ingestion	2	0.003	0.133	Rare
Thermal	1	0.002	0.067	Rare

Table 12: Analysis by injury.

By frequency, firefighting was almost three times more likely to result in a reportable event compared to any other activity with an occurrence of 21.8 times per year. Road crash rescue (RCR) response resulted in 7.3 reportable events per year whilst bushfire fighting resulted in 6.6 reportable incidents per year. This result suggest additional attention should be provided in training personnel and developing suitable risk mitigation procedures the activities most likely to give rise to a reportable incident.

In terms of risk source, Physical Strain is almost 1.8 times more likely to result in a reportable event compared to other risk sources. This is consistent with the physically demanding nature of firefighting reported by DFES (2013b) and is comparable to overexertion/strain injury rates

in United States firefighters reported by FEMA (2011). The high rate of reportable events resulting from Physical Strain is significant as physical strain may be in part preventable through the implementation of a suitable physical fitness program. Winter et al. (2010, p235) conclude however that any such program "*must be positive and not punitive in design; require mandatory participation by all uniformed personnel; allow for age, gender, and position in the department; allow for on-duty-time participation utilizing facilities provided by the department; provide for rehabilitation and remedial support for those in need; and contain training and education components*."

Exposure to various hazards including asbestos, chemicals and biohazards collectively accounts for more reports than any other risk source (total of 225 incidents with a conditional probability of 0.338). Such exposures are impossible to eradicate due to the inherent nature of all hazards emergency response. However the likelihood of adverse outcomes can be in part mitigated through procedural and tactical measures. Such an approach is best illustrated using a bow tie analysis (Robinson et al, 2010) as shown in Figure 5. In this manner both pre-exposure and post exposure controls or barriers can be implemented holistically to reduce the likelihood and severity of adverse consequences. The bow tie analysis also facilitates the illustration of relationships between various barriers. Figure 5 provides a simple example of this in the firefighting context. Where a relationship exists between barriers, the influence of the preceding barrier may be either agonistic or antagonistic on the effectiveness of the following barrier. For example, inappropriate or insufficient research and data may lead to inappropriate organisational policy. This in turn can result in inappropriate training which will ultimately weaken risk management at all operational and organisational levels. The combined

effect of the barriers and intrinsic relationships can ultimately affect the severity of realised consequences.

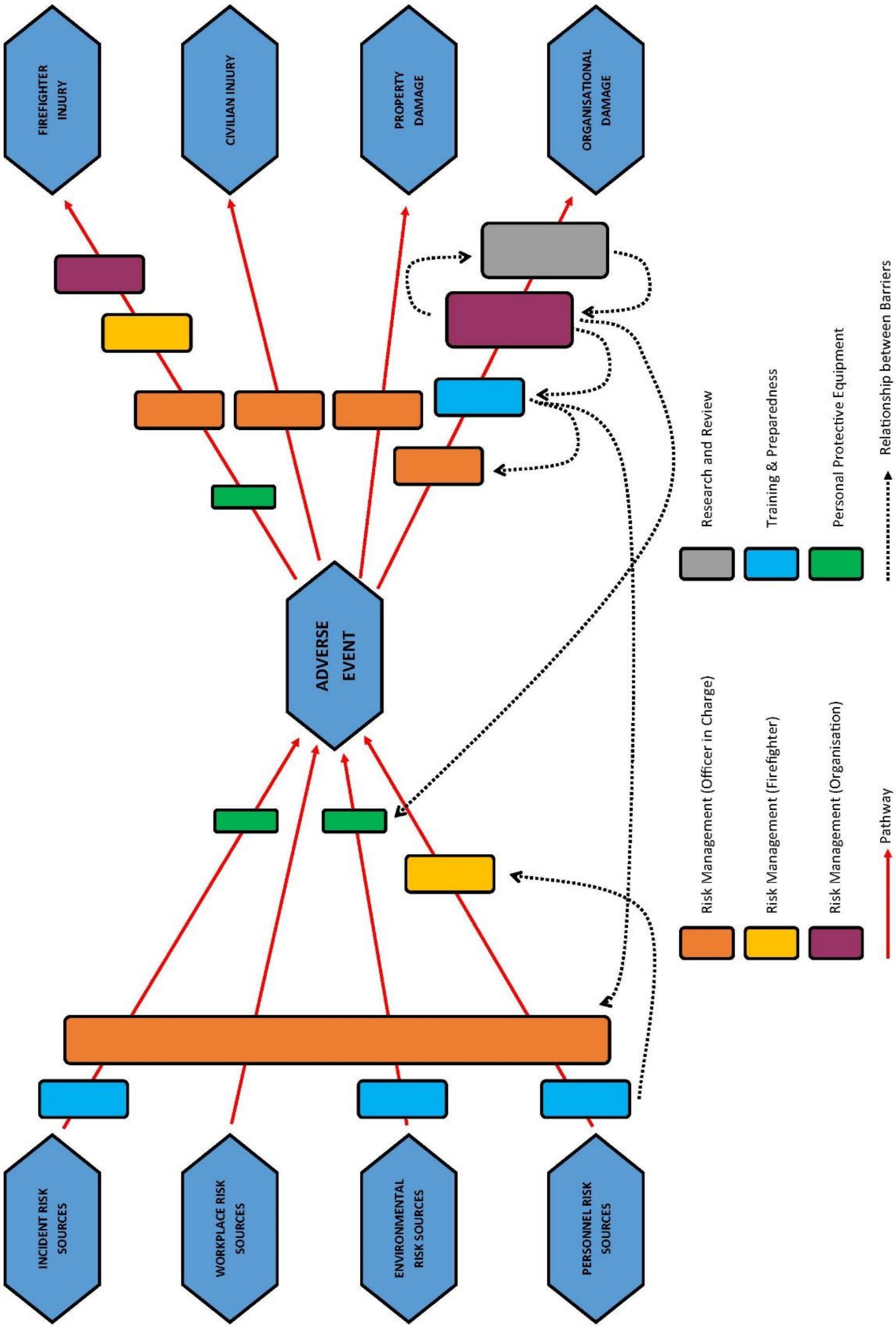

Figure 5: Simplified bow tie contextualised to firefighting operations

Just as firefighting is extremely physically demanding, it is also psychologically demanding with exposure to psychological trauma identified as the second most common risk source resulting in reportable events. Carll (2007) and Trappler (2014) concur that care must be taken in addressing exposures of a psychological nature in firefighting which are unique to the emergency service profession. Just as education, awareness and resilience training is important prior to exposure, specific psychological management programs and counselling are required post exposure.

Analysis by injury yields results that in limited circumstances appear to conflict with other available data sets. Inhalation 'injuries' are the most probable of all classified injuries to occur. However, this may be explained by the fact that all incidences of "inhalation" of smoke or other chemicals that were reported are captured in this category, regardless of whether acute injury occurred. Psychological 'injuries' were the second most common reported injuries and this is consistent with the analysis of risk source data. Surprisingly thermal injuries, being those resulting from heat transfer were the least probable (0.002 conditional probability). This conflicts with data reported by FEMA (2011, 2012) which identifies a significantly higher thermal injury occurrence rate. The calculated figure may be lower than the actual number of injuries as a result of thermal impacts as it is suggested that many incidents may remain unreported (DFES Health and Safety Services, 2015). The probability of "Nil" injuries occurring represents "Near Misses" where no injury was actually sustained and is the third highest amongst reported injuries sustained. Again this figure may be lower than the actual number of near misses that occur during incidents due to the lack of report completion when near misses occur.

Tables 13 to 24 report the conditional probability of a specific injury occurring given an injury occurs during the specified activity. Across all activities, the "Nil" injury or 'near miss' is prevalent. This is consistent with previous findings and suggests a large number of incidents occur with the potential to cause injury but do not actually cause injury in the specific case reported. Psychological injuries are also well represented throughout the reports, particularly where the potential or realisation of human trauma is present (for instance Road Crash Rescue and Suicide Response). In the case of reported injuries during Suicide Response it is suggested it is likely the "Not Reported" values should actually also be psychological injuries but have not been documented as such in the relevant reports.

Injury	Conditional Probability
Nil	0.300
Back	0.150
Knee	0.150
Head / spinal	0.100
Heat illness	0.100
Neck	0.100
Ankle	0.050
Shoulder	0.050

Table 13: Conditional probability of specific injury during Breathing Apparatus operations.

Injury	Conditional Probability
Eye	0.253
Knee	0.141
Nil	0.131
Back	0.081
Inhalation	0.061
Leg	0.061
Ankle	0.051
Shoulder	0.051
Foot	0.030
Heat illness	0.030
Finger	0.020
Neck	0.020
Arm	0.010
Chest	0.010
Elbow	0.010
Face	0.010
Multiple	0.010
Psychological	0.010
Wrist	0.010

Table 14: Conditional probability of specific injury during Bushfire operations.

Injury	Conditional Probability
Eye	0.800
Knee	0.200

Table 15: Conditional probability of specific injury during Direct Brigade Alarm response.

Injury	Conditional Probability
Nil	0.800
Back	0.033
Ear	0.033
Leg	0.033
Psychological	0.033
Shoulder	0.033
Wrist	0.033

Table 16: Conditional probability of specific injury during Driving operations.

Injury	Conditional Probability
Finger	0.375
Nil	0.250
Arm	0.125
Elbow	0.125
Heat illness	0.125

Table 17: Conditional probability of specific injury resulting from Environment related incidents.

Injury	Conditional Probability
Inhalation	0.434
Back	0.092
Heat illness	0.067
Knee	0.064
Nil	0.064
Shoulder	0.046
Head / spinal	0.034
Leg	0.028
Arm	0.024
Multiple	0.018
Foot	0.015
Hand	0.015
Ear	0.012
Psychological	0.012
Ankle	0.009
Elbow	0.009
Eye	0.009
Finger	0.009
Neck	0.009
Abdominal	0.006
Chest	0.006
Hip	0.006
Face	0.003

Groin	0.003
Thermal	0.003

Table 18: Conditional probability of specific injury during Firefighting operations.

Injury	Conditional Probability
General	0.500
Inhalation	0.417
Heat illness	0.083

Table 19: Conditional probability of specific injury during Hazardous Materials operations.

Injury	Conditional Probability
Knee	0.500
Psychological	0.500

Table 20: Conditional probability of specific injury during operations not specified (Not Reported).

Injury	Conditional Probability
Psychological	0.600
Back	0.100
General	0.082
Face	0.045

Absorption	0.018
Inhalation	0.018
Shoulder	0.018
Ankle	0.009
Arm	0.009
Finger	0.009
Groin	0.009
Hand	0.009
Heat illness	0.009
Hip	0.009
Ingestion	0.009
Knee	0.009
Multiple	0.009
Neck	0.009
Nil	0.009
Wrist	0.009

Table 21: Conditional probability of specific injury during Road Crash Rescue operations.

Injury	Conditional Probability
Psychological	0.306
Inhalation	0.194
Back	0.083
Nil	0.083

Absorption	0.056
Shoulder	0.056
Ankle	0.028
Elbow	0.028
Groin	0.028
Hand	0.028
Ingestion	0.028
Knee	0.028
Not reported	0.028
Wrist	0.028

Table 22: Conditional probability of specific injury during Rescue (other than RCR) operations.

Injury	Conditional Probability
Face	0.500
Inhalation	0.500

Table 23: Conditional probability of specific injury during Storm operations.

Injury	Conditional Probability
Psychological	0.800
Not reported	0.200

Table 24: Conditional probability of specific injury during Suicide Response operations.

Analysis reveals thermal injuries account for a relatively insignificant conditional probability of only 0.003 during Firefighting activities only. No thermal burns are reported during Bushfire or other response. This is in stark contradiction to the probability of thermal injuries in United States statistics (FEMA, 2012). However, it is hypothesised that this may be in part due to under reporting of thermal injuries, due to thermal injuries being referred to as injuries to specific body parts without reference to the burn trauma or differences in firefighting tactics between Australia and the United States which may result in different mechanisms and frequencies of injury.

For example, inhalation injuries appear over-represented in the data which is considered surprising given the significant respiratory protection available to responding crews (DFES 2012a, 2012b, 2015a,). Analysis of the report descriptions suggests that a significant proportion of inhalation exposures are due to incorrect fitting respiratory protection that do not provide adequate seals. This has recently been in part rectified through the implementation of full face respirators (DFES, 2015e). The conditional probability of heat illness occurrence also warrants attention with prevalence amongst all operations and responses that require the responder to wear structural firefighting Personal Protective Equipment (PPE) and require significant physical effort.

Review of the conditional probabilities detailed above can assist incident controllers having enhanced evidence based awareness of potential consequences and likelihoods prior to their occurrence during an emergency incident. Analysis of the conditional probability of injury given an injury occurs during each of the specific operations will also facilitate the review and

improvement of strategic and tactical planning; personnel relief requirements; the potential effectiveness of PPE; and even guide the potential development of targeted prophylactic physical training programs.

Tables 25 to 36 provide perhaps some of the most beneficial data to facilitate the development of evidence based risk mitigation strategies prior to and on the incident ground. Physical Strain recurrently accounts for high, if not the highest, level of Risk Source giving rise to a reportable incident across nearly all activities. This finding is consistent with the previous results of both this study and FEMA (2011) and reaffirms the notion that firefighting is extremely physical in nature (DFES, 2013b; Penney, 2013). It is suggested that a lack of physical wellness may be the primary contributor to reportable incidents as a result of Physical Strain. For example, Moore-Merrell et al. (2008) observed that physical strain was the second highest contributing factor to firefighter injury in the United States (the first being a lack of situational awareness).

Initiating Event	Conditional Probability
Physical Strain	0.550
Impact	0.150
Entrapment	0.100
Equipment failure	0.100
Communications	0.050
Electrical	0.050

Table 25: Conditional probability of specific initiating events (Risk Sources) during Breathing Apparatus operations.

Initiating Event	Conditional Probability
Physical Strain	0.515
Exposure - smoke	0.253
Exposure - chemical	0.061
Impact	0.051
Thermal	0.051
Exposure - asbestos	0.030
Equipment failure	0.020
Exposure - psychological	0.010
Violence	0.010

Table 26: Conditional probability of specific initiating events (Risk Sources) during Bushfire fighting operations.

Initiating Event	Conditional Probability
Impact	0.600
Exposure - chemical	0.400

Table 27: Conditional probability of specific initiating events (Risk Sources) during Direct Brigade Alarm response.

Initiating Event	Conditional Probability
Operator error	0.300
Equipment failure	0.267
Environmental	0.133
Impaired Vision	0.133
Other person	0.133
Exposure - psychological	0.033

Table 28: Conditional probability of specific initiating events (Risk Sources) during Driving operations.

Initiating Event	Conditional Probability
Animal	0.875
Physical Strain	0.125

Table 29: Conditional probability of specific initiating events (Risk Sources) during Environment related incidents.

Initiating Event	Conditional Probability
Physical Strain	0.358
Exposure - asbestos	0.315
Impact	0.104

Exposure - hazmat fire	0.073
Exposure - smoke	0.037
Thermal	0.034
Equipment failure	0.024
Communications	0.012
Exposure - chemical	0.009
Exposure - psychological	0.009
Blast/Explosion	0.006
Exposure - noise	0.006
Operator error	0.006
Not reported	0.003
Violence	0.003

Table 30: Conditional probability of specific initiating events (Risk Sources) during Firefighting operations.

Initiating Event	Conditional Probability
Exposure - chemical	0.583
Exposure - asbestos	0.333
Physical Strain	0.083

Table 31: Conditional probability of specific initiating events (Risk Sources) during Hazardous Materials operations.

Initiating Event	Conditional Probability
Exposure - psychological	0.500
Physical Strain	0.500

Table 32: Conditional probability of specific initiating events (Risk Sources) during operations Not Recorded.

Initiating Event	Conditional Probability
Exposure - psychological	0.600
Physical Strain	0.209
Exposure - biohazard	0.164
Exposure - asbestos	0.018
Impact	0.009

Table 33: Conditional probability of specific initiating events (Risk Sources) during Road Crash Rescue operations.

Initiating Event	Conditional Probability
Exposure - psychological	0.306
Physical Strain	0.278
Exposure - asbestos	0.194

Exposure - biohazard	0.111
Impact	0.056
Equipment failure	0.028
Exposure - chemical	0.028

Table 34: Conditional probability of specific initiating events (Risk Sources) during Rescue (other than RCR) operations.

Initiating Event	Conditional Probability
Exposure - asbestos	0.500
Impact	0.500

Table 35: Conditional probability of specific initiating events (Risk Sources) during Storm response.

Initiating Event	Conditional Probability
Exposure - psychological	0.800
Exposure - biohazard	0.133
Exposure - chemical	0.067

Table 36: Conditional probability of specific initiating events (Risk Sources) during Suicide Response operations.

Psychological Exposure was also well represented in the data, particularly amongst incident response involving human life and trauma including Road Crash Rescue and Suicide Response. This again supports previous findings of the study.

Exposure to various contaminants was also again prevalent throughout the majority of fields. This may be significant as the potential effects may be mitigated through appropriate strategic and tactical response; appropriate PPE and suitable decontamination procedures (DFES, 2015a, 2015b).

Breathing Apparatus operations are amongst the most hazardous of all firefighting activities, involving the use of self-contained breathing apparatus in atmospheres not conducive to life due to the presence of smoke, heat, oxygen deficiency and/or excessive temperature (DFES, 2015b). During Breathing Apparatus operations teams of two firefighters will work in close proximity or inside burning structures and typically rely on a single line of firefighting hose for fire protection. The margin for error is therefore understandably narrow and the potential severity of consequences comparatively high (as reported in Table 37). Operations are extremely physical in nature and this is represented by a conditional probability of 0.55 that the responsible risk source for the reportable event will be Physical Strain. Analysis also revealed a conditional probability of Impacts being the responsible risk source for the reportable incident of 0.15. It is suggested Impacts (as opposed to Explosion / Blasts) are more likely to occur within the burning structure and subsequently this figure may be reduced through the defining of organisational risk acceptance thresholds. In turn, this would facilitate

a reduction in the potential for incident controllers committing crews to internal firefighting in the absence of life involvement because of a perceived internal or external obligation to do so.

Consequence Severity	Actual	Potential
Insignificant	0.300	0.000
Minor	0.700	0.150
Moderate	0.000	0.400
Major	0.000	0.250
Catastrophic	0.000	0.200

Table 37: Conditional probability of actual and potential consequence severity during Breathing Apparatus operations.

Tables 37 to 48 provide comparison between actual reported consequence severity and potential consequence severity for each Activity. Analysis reveals the conditional probability of moderate to catastrophic potential consequence severity is higher than actual reported consequence severity across all Activity groups. This may be in part explained by the lack of subsequent reports or follow up detail for consequences that may have a long period of latency (for instance psychological exposures, exposures to contaminants) or for injuries that are initially reported but worsen over time. The results of this analysis also support previous findings of the prevalence of "Nil" reported injuries in that there is a high conditional probability of 'near misses' in the incidents reported.

Consequence Severity	Actual	Potential
Insignificant	0.818	0.000

Minor	0.131	0.505
Moderate	0.040	0.101
Major	0.010	0.212
Catastrophic	0.000	0.182

Table 38: Conditional probability of actual and potential consequence severity during Bushfire Fighting operations.

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Consequence Severity	Actual	Potential
Insignificant	1.000	0.000
Minor	0.000	0.600
Moderate	0.000	0.000
Major	0.000	0.400
Catastrophic	0.000	0.000

Table 39: Conditional probability of actual and potential consequence severity during Direct Brigade Alarm response

Consequence Severity	Actual	Potential
Insignificant	0.967	0.133
Minor	0.033	0.100
Moderate	0.000	0.100
Major	0.000	0.167
Catastrophic	0.000	0.500

Table 40: Conditional probability of actual and potential consequence severity during Driving operations.

Consequence Severity	Actual	Potential
Insignificant	0.750	0.125
Minor	0.250	0.125
Moderate	0.000	0.750
Major	0.000	0.000
Catastrophic	0.000	0.000

Table 41: Conditional probability of actual and potential consequence severity during Environmental related incidents.

Consequence Severity	Actual	Potential
Insignificant	0.933	0.031
Minor	0.034	0.147
Moderate	0.021	0.199
Major	0.012	0.098
Catastrophic	0.000	0.526

Table 42: Conditional probability of actual and potential consequence severity during Firefighting response.

Consequence Severity	Actual	Potential
Insignificant	1.000	0.000
Minor	0.000	0.000
Moderate	0.000	0.000

Major	0.000	0.083
Catastrophic	0.000	0.917

Table 43: Conditional probability of actual and potential consequence severity during Hazardous Materials response.

Consequence Severity	Actual	Potential
Insignificant	1.000	0.000
Minor	0.000	0.000
Moderate	0.000	1.000
Major	0.000	0.000
Catastrophic	0.000	0.000

Table 44: Conditional probability of actual and potential consequence severity during operations Not Recorded.

Consequence Severity	Actual	Potential
Insignificant	0.973	0.000
Minor	0.018	0.073
Moderate	0.009	0.218
Major	0.000	0.027
Catastrophic	0.000	0.682

Table 45: Conditional probability of actual and potential consequence severity during Road Crash Rescue Operations.

Consequence Severity	Actual	Potential
Insignificant	0.972	0.000
Minor	0.000	0.111
Moderate	0.028	0.306
Major	0.000	0.056
Catastrophic	0.000	0.528

Table 46: Conditional probability of actual and potential consequence severity during Rescue operations (other than Road Crash Rescue).

Consequence Severity	Actual	Potential
Insignificant	1.000	0.000
Minor	0.000	0.000
Moderate	0.000	0.000
Major	0.000	0.500
Catastrophic	0.000	0.500

Table 47: Conditional probability of actual and potential consequence severity during Storm related response.

Consequence Severity	Actual	Potential
Insignificant	1.000	0.000
Minor	0.000	0.133
Moderate	0.000	0.000

Major	0.000	0.000
Catastrophic	0.000	0.867

Table 48: Conditional probability of actual and potential consequence severity during Suicide Response operations.

Further analysis reveals that, based on actual consequence severity, there is a conditional probability of zero (0.000) for a catastrophic severity consequence occurring across the entire Activity range. This result is not supported by numerous international studies (FEMA, 2011, 2012; Moore-Merrell et al., 2008) and is suggested to have occurred as a result of inadequate reporting of significant injuries. By comparison, a mean potential catastrophic severity consequence conditional probability across all Activities of 0.408 (Standard deviation of 0.328) was calculated. These results represent a significant potential for increased severe injury, permanent disability and even death amongst the study group and must be considered in the establishment of the internal context for risk management during dynamic emergency operations.

4.2.3 Summary of Findings:

Analysis of the results of phase two can be summarised as:

1. Results must be interpreted with some caution. It is suggested current recording processes do not provide sufficient data to accurately determine the realisation of injury or illness with extended latency (psychological trauma for instance). Current recording

processes also do not provide for accumulation injuries as a result of repetitious exposure, with injuries being assigned to a single event;

2. It is almost certain that a reportable event will occur during the majority of types of incident response. This is consistent with the notion that firefighting is an inherently dangerous occupation;
3. Physical strain is the highest cause of reportable event all Activities considered. This is consistent with international data (FEMA, 2011; Merrill-Moore et al., 2008);
4. Different Activities are associated with differing injury probabilities. Whilst this study provides limited analysis of the results further study in this area may facilitate the development of targeted mitigation strategies during preparation for, and response to, specific emergency incidents in order reduce the occurrence of certain adverse outcomes;
5. Exposure to various contaminants is prevalent across all Activity groups. This is consistent with the nature of firefighters responding to a large range of firefighting, rescue and hazardous materials incidents. As the specific nature of contamination and / or product identification often remains undocumented few beneficial conclusions can be drawn from the study data in this area. An opportunity for future study in this area exists once suitable data is collected;
6. The potential consequence is consistently greater than the actual consequence realised in the data analysed. This may be explained by the mitigating effects of post event barriers (PPE, physical conditioning of personnel etc) or simply the personnel involved escaped more serious injury due to a combination of events that lead to them being close to as opposed to being in the direct line of impact; and

7. During almost all types of operational response the potential for major or catastrophic adverse outcomes is present.

4.3 Summary

4.3.1 Limitations

There are a number of limitations that may affect the validity of the findings of this study. Foremost is the relatively small number of priors available for analysis and the lack of sufficient detail with which to complete comprehensive analysis. Whilst all care and due diligence has been undertaken to the extent practicable to provide unbiased and accurate analysis, enhanced data sets would facilitate greater certainty of the findings reached.

Another limitation is the reliance of United States statistics on which to make comparison to the injury data obtained as firefighting tactics may vary between Australian and American services. Australian tactics, particularly in the structural fire setting may be more closely aligned with United Kingdom fire services, however available data for comparison was not found as records did not identify type of injury or activity at time of injury (DCLG, 2012).

These limitations, in addition to those discussed in section 3.3.3 of this report are not fatal, but rather should be acknowledged when the presented conclusions are considered.

4.3.2 Research Implications

This research has the potential to significantly improve the process of risk management in dynamic emergency situations the Western Australian Department of Fire and Emergency Services and other emergency services throughout the world. It achieves this by not only identifying inconsistencies and shortfalls of current practice, but also by identifying the necessary steps required in order to align risk management during emergency situations with AS31000.

Perhaps most importantly, this research explicitly rejects any notion of the validity of "dynamic risk management" being a stand-alone process for managing risk during emergency situations. For best practice to be realised the architectural structure or process of risk management cannot change. The context in which risk management is completed may vary in dynamic emergency situations compared to that of corporate boardrooms, however it is this unique and dynamic context of emergency situations that only further requires the AS31000 risk management process to be completed in its entirety each and every time risk is assessed and subsequently managed. In order to achieve this, emergency services must first succinctly define their organisational risk attitudes during emergency situations (which will inevitably vary from risk attitudes during normal business) and educate their personnel appropriately so that it forms part of the subconscious and conscious incident risk management process.

This education must occur at the earliest stage of a firefighter's career to ensure appropriate and consistent risk contexts, tolerance and management are indoctrinated into all facets of emergency response. It is only through such education that AS31000 compliant risk management will be able to be completed in the dynamic emergency environment, not only by

incident controllers, but by all personnel on at the incident. This will foreseeably result in safer work practices, better decisions and reduced adverse outcomes for both individuals and organisations.

4.3.3 Further Research

This study has also highlighted a number of opportunities for further study in the field.

Repetition of this study incorporating the entire population of incident controllers within DFES would allow greater analysis of current risk attitudes and may serve to enhance the definition of the internal DFES context.

Repetition of this study using those persons or agencies that may be involved in a critical external review or practices, such as WorkSafe, would significantly enhance the understanding of the external context and expectations in which DFES operates. This may have the additional benefit of enabling DFES to align internal and external risk attitudes so that conflicting attitudes are not found to be a source of adverse outcomes. In this manner, even should an adverse outcome be realised, organisational risk attitudes would be consistent with external legislative requirements. Once these attitudes are adopted and personnel appropriately educated this would also foreseeably lead to improved practice during dynamic emergency incidents. It should be noted however that any external parties included in such as study would need to have a sound understanding of the DFES internal context so that findings are applicable to the incident ground.

Comparable studies in other emergency services throughout Australia will facilitate critical analysis of the validity of the findings of this study throughout the Australian context. It would also significantly enhance the priors available for analysis of conditional probability which in turn would enhance the validity of findings.

5.0 Conclusion

Published literature revealed significant variance in the extent of defined risk thresholds amongst international fire services with an almost total absence within Australian fire services. The literature also identified that whilst almost all emergency services acknowledged the importance of adaptive and responsible incident management during dynamic emergency operations, with the exception of the United Kingdom Fire Service, application of the AS31000 process was at best partial and in some international cases completely abandoned. Non-compliances were found to be undefined organisational risk attitudes; external contexts remaining unacknowledged; and only partial application of the processes defined in AS31000. In particular, the perception that the risk management process itself changed during dynamic emergency operations as opposed to the process being continually repeated in its entirety with varying risk thresholds within the context of the environment and the dynamics of each individual emergency at the point in time the risk assessment is conducted must be addressed.

Results of this research confirmed conclusions within the literature review. Incident controllers were found to rely on professional craft knowledge evolved through their own subjective experiences. Whilst historical incident management practices have arguably been effective in the prevention of severe injury amongst responding personnel (an average conditional probability of 0.893 of 'Nil' injury across all activities being calculated), they have arguably also been non-compliant with AS31000. This may have significant implications on the facilitation of post incident reviews and forensic reports as it is almost certain that the consensus on risk acceptance by the authors of these reviews and reports will vary from that of the incident controller at the time of the emergency incident. Ramifications of any non-

compliance would only increase should a catastrophic consequence be realised and a review be conducted by an external party who cannot reference the internal fire service context and whom would rely solely on AS31000 as the required standard.

Whilst historically proven to be highly effective without further definition and dissemination of internal contexts and risk thresholds, risk management during dynamic emergency operations in the Western Australian fire and emergency service is not considered currently compliant with AS31000.

This research also highlighted the need for organisations to have defined risk acceptance criteria for incident controllers to reference in order to reduce the potential for individual bias or conflicting operational strategies between incident controllers at strategic levels and officers involved in tactical front line response (where the exposure transfers from personnel under the incident controller's command to the personnel themselves).

The answer may lie in several targeted responses:

1. Enhanced reporting to facilitate information rich data with which to better define specific emergency services risk;
2. Implementation of probability based risk modelling to assist evidence based risk management at all levels of emergency incidents;
3. Defining and communicating DFES operational risk thresholds; and
4. Adoption of the philosophies and processes of DCLG (2008, 2012) contextualised to the internal and external contexts of DFES.

By providing consistent risk threshold guidance throughout a firefighter's and officer's career the potential for adverse outcomes will foreseeably reduce. Further research, improved data collection and ongoing review at strategic and operational levels is also essential to enhance dynamic incident risk management in an ongoing and AS31000 compliant basis.

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