DOCTOR OF PHILOSOPHY

A Human Factors analysis of Firefighter injury sustained during emergency response operations
Implications for error management and injury reduction in English Fire and Rescue Services.

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Coventry University

By

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(Doctor of Philosophy)

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By

William A M Gough

A thesis submitted in partial fulfilment of the University's requirementsfor the degree of Doctor of Philosophy

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Certificate of Ethical Approval

Applicant:

William Gough

Project Title:

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This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

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A Human Factors analysis of Firefighter injury sustained during emergency response operations: Implications for error management and injury reduction in English Fire and Rescue Services.

Abstract

This research is concerned with the human factors that may contribute to firefighter injury and whether the Fire and Rescue Service (FRS) adequately acknowledges their influence when investigating, recording, analysing, or reporting accident causation. In particular, the extent to which, as critical decision makers, firefighters experience the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander. Studies of judgement and decision making specifically focused on the role of firefighter as opposed to their incident commanders are exceptional.

For the first time in the analysis of firefighter injury, a number of variables that represent the preconditions of accident causation such as the demographic, temporal, environmental and contextual characteristics were analysed. An ‘error typing’ taxonomy that differentiates between decision errors, skill-based errors, perception errors and violations was used to examine the extent to which human factors are being considered by FRSs in the analysis of firefighter injury. Opportunity was also taken to examine the applicability of the Human Factors Analysis and Classification System (HFACS) (Weigmann and Shappell 2003), to the emergency response domain of the FRS. This revealed the value of developing a valid and reliable sector specific variant of HFACS (UKFire-HFACS). Finally, using the critical decision method, recollection of the contextual characteristics that influenced the judgements, decisions, and actions at the ‘moment-of-choice’ of injured firefighters was also explored. Three studies that when combined establish components of a Human Factors Analysis Framework (HFAF) for the FRS.

It was established that when implementing the requirements of an incident commander’s tactical plan, firefighters are required to make critical decisions and at times experience injury when operating without the immediate oversight of a supervisor or commander. Analysis demonstrated how the majority of injuries involve either a decision based or skill-based error which substantiates the existence and influence of skill fade at the ‘moment-of-choice’. It also brings FRS arrangements for the maintenance of competence into focus and worthy of closer scientific scrutiny. It is also evident that the approach of this research using three studies can be developed into a human factors analysis framework for the FRS. In turn this can establish the means by which the deficit outcome of firefighter critical decision making can be better understood, enable targeted intervention, and over time, reduce reported operational injury.

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Glossary of Frequently Used Abbreviations

AED	Active Error Descriptor
ARA	Analytical Risk Assessment
BOS	Bristol Online Surveys
CDM	Critical Decision Method
CFO	Chief Fire Officer
CFOA	Chief Fire Officers Association
CM	Crew Manager
CRM	Crew Resource Management
CS1	Case Study 1
CS2	Case Study 2
DCLG	Department for Communities and Local Government
DCP	Decision Control process
DRA	Dynamic Risk Assessment
ECFA	Events and Conditional Factors Analysis
FBU	Fire Brigades Union
FDS	Flexible Duty System
FRA	Fire and Rescue Authority
FRS	Fire and Rescue Service
GEMS	Generic Error Modelling System
HF	Human Factors
HFACS	Human Factors Analysis and Classification System
HFAF	Human Factors Analysis Framework
HRO	High Reliability Organisation
HSE	Health and Safety Executive
HVHF	High Velocity Human Factors
IC	Incident Commander
IRA	Individual Risk Assessment
IP	Injured Party
Kα	Krippendorff's Alpha Diagnostic
LGA	Local Government Association
NOG	National Operational Guidance
NOL	National Operational Learning
NOS	National Operational Standards
NDM	Naturalistic Decision Making
OiC	Officer in Charge
OSB	Operational Statistics Bulletin
Orgax	Organisational Accidents
PPE	Personal Protective Equipment
PR	Persons Reported
RDS	Retained Duty System
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
RPD	Recognition Primed Decision making
RQ1	Research Question 1
RQ2	Research Question 2

RQ3	Research Question 3
RTC	Road Traffic Collision
SA	Situation Awareness
SCBA	Self-contained Breathing Apparatus
SCM	Swiss Cheese Model
SME	Subject Matter Expert
SOP	Standard Operating Procedure
SPoC	Single Point of Contact
SRK	Skill-rule-knowledge Classifications
The Maxim.	The Firefighter's Safety Maxim
WDS	Whole-time Duty System
WM	Watch Manager

CONTENTS

1. INTRODUCTION.

1.1 Introduction.

This research originated from a professional life experience involving participation in the investigation of the death of two firefighters during a fire in a residential high rise building April 2010, circumstances reflected upon later in this chapter. Since then, a further 10,516 firefighters have reported being injured during emergency response operations throughout England. 333 sustained major injuries and sadly, a further two fatalities have occurred (Home Office 2021). In a desire to generate 'cross organisational isomorphism' (Toft and Reynolds 2005), only in the last 15 years has the Fire and Rescue Service (FRS) publicly shared in any detail reports of their investigations following such events. The reports that have been published are those involving fatalities and they have now reached double figures. They contain many recommendations; some being repeated in reports published years apart. Recommendations that seek improvement in regulation, practice, procedure, technology, and equipment. Recommendations designed to protect the operator - the firefighter at the sharp end (Flin, O'Connor and Crichton 2008) and avoid recurrence.

In their discussion of causal factors, those FRS reports that have been published observe contemporary convention of event analysis from the point where system defences failed, allowing a confluence of accident-causing conditions, to a more distal point of origin in the FRS system of governance. Rarely do they focus on the fallibility of the human condition at the point of the 'active error', or the human factors of the preconditions that may have influenced an unintended unsafe act. Instead, they almost always find origin in the involvement of the human in the hierarchical structures, governance, and practices of the broader error management landscape of the FRS.

This approach may have several origins. It may lie in the pursuit or avoidance of litigation or in the desire to deflect blame away from the victims and their fallibilities. It may even be influenced by the chosen method of causal factor analysis where the focus is on systemic failings and avoids scrutiny of the behaviours of those directly involved. Nevertheless, at the point of confluence, amongst the conditions that combine to allow an accident to occur, humans will play a part. Not only those removed in time and distance elsewhere in the organisational system, but also those proximal to events as they unfold. This is where, in the safety management system of an FRS, the firefighter is the last opportunity to intervene and mitigate the effects of accident-causing conditions. The last barrier in the defensive system arguably not just that of an FRS but, in certain circumstances, also society's last line of defence.

The limited number of investigations that have been widely published are authored by investigators and analysts who have scrutinised in detail what they believe to be causal factors in what some researchers describe as a sequence or chain of events, and others more complex systemic characteristics (Heinrich 1941, Hollnagel 1998, Leveson 2004, Reason 1990). Often, human frailties at the sharp end of activities are either avoided or left to the reader to discern their contribution to the confluence of conditions. It is also the case that if only a handful of the more serious fatal accident and injury reports have been published, there are many thousands that have not. Yet, their data may hold the isomorphic key to strengthening the system constraints and defences of the FRS as a sector, rather than the single individual FRS dealing with an accident.

Some accident and injury data arising from emergency response operations were published by the Government's Department for Communities and Local Government (DCLG) in an annual Operational Statistics Bulletin (OSB), (DCLG 2015). Even when responsibility for publishing this data was transferred to the Home Office in January 2016, it remains the case that despite there being many human and environmental factors that could be considered relevant to the confluence of conditions that result in injury, the published performance data offers limited value to any sector wide intervention strategy.

However, there are many environmental, contextual, psychological and psychosocial factors with attendant data that FRSs have access to in the process of investigation. Data that could better inform subsequent intervention strategies but rather than currently focus on a small number of serious events, capture the isomorphic qualities of many hundreds if not thousands.

This research sets out to examine several contextual factors that influence the decision making, actions and behaviours of firefighters when attending operational incidents which can result in either injury to themselves or other firefighters. By evaluating those factors that influence the situation awareness, judgements, decisions and behaviours of firefighters prior to and at the ‘moment-of-choice’; the main aim of this research is to improve error management and contribute to injury reduction in the Fire and Rescue Service.

In achieving this aim, the analysis of firefighter injury sustained during emergency response operations has two objectives. Firstly, to identify the extent to which FRSs gather, analyse and understand data relating to the preconditions, unsafe acts and decision-making deficit of reported operational injury. In particular, the extent to which as critical decision makers, firefighters experience the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander. The second objective is to determine if a sector specific analysis tool can be developed and used to better understand the human factors of accident causation and inform targeted intervention strategies. In pursuing this aim and objectives the literature review of Chapter 2 explores original and contemporary research into accident causation analysis models, tools and techniques, and contemporary thinking about judgement and decision making in order to establish their relationship with accident causation in the FRS context.

The research methodology of Chapter 3 uses a pragmatic philosophical positioning to describe the approach taken in developing three separate studies designed to analyse the extent to which human factors are captured, reported, and interpreted to better understand accident causation in the emergency response domain of the FRS. Chapter 4 describes the analysis and results of the first of these studies where quantitative methods are used to examine several variables that could better inform the preconditions of accident causation. Here descriptive analysis explores demographic, temporal, environmental and contextual characteristics of reported injury in the year of the study (2015/16). Important to this study is the application of an error typing taxonomy that establishes 'active error descriptors' (AEDs) which differentiate between decision errors, skill-based errors, perception errors and violations. Analysis of these active error descriptors further exposes aspects of accident causation that could enable the FRS to target intervention strategies.

Based on AEDs and using error typing for the first time, the judgements of the participating FRS managers of the first study form the focus of interest of Study 2. Chapter 6 explores the potential for capturing and learning from data relating to unsafe acts, their preconditions, and supervisory and organisational influences applicable to accident causation in the FRS. The opportunity is also taken to examine consistency in the judgements of the participants when using a suitable Human Factors (HF) analysis tool. The application of the Weigmann and Shappell (2003) Human Factors Analysis and Classification System (HFACS), to two case studies involving fatal injuries in the emergency response domain is used to examine the level of agreement before and after the tool is modified to a more sector specific variant. In doing so, the study reveals great value in the continued development of HFACS to a valid and reliable FRS variant (UKFire-HFACS). Chapter 5 describes the analysis and results of the human factors analysis study and also offers discussion on the use of a FRS sector specific Human Factors analysis framework (HFAF) to better inform FRS understanding of accident causation.

The psychological precursors that influence the 'moment-of-choice' and critical decision making of firefighters when operating without the immediate oversight of a supervisor or commander forms the focus of the third study. Designed to improve understanding of the 'moment-of-choice', Chapter 6 provides an analysis of environmental and contextual characteristics acting as psychological preconditions described by the introspective recollections of a small group of firefighters, supervisors and commanders who experienced the deficit outcome of their own risk-v-benefit decisions.

Informed by issues emerging from the contemporary architecture of error, the discussion of Chapter 7 first considers the key findings of the three studies described above before deliberating on the limitations and strengths of the research design and approach. The chapter then concludes with discussion on the value the research holds for the fire and rescue sector. Discussion confirms that critical high risk – high benefit decisions are not exclusive to the domain of incident supervisors and commanders and the deficit outcome of the critical decision making of firefighters can largely be attributed to skill-based and decision-based errors. Their prominence not only supports the existence and influence of skill fade affecting the 'moment-of-choice' of firefighters, but also the need for closer scrutiny of FRS arrangements for establishing and maintaining competence. Furthermore, the prominence of decision-based errors would sustain the argument for firefighters having to acquire and demonstrate an enhanced level of critical decision-making knowledge and exposes the need for closer scrutiny of knowledge acquisition and understanding of those in the role of firefighter by both academics and practitioners.

Finally, Chapter 8 draws the thesis to conclusion identifying specific areas of research that would lead to improved FRS understanding of the human factors of accident causation which should act as catalyst to future research. The conclusion argues that the three study approach adopted by this research offers a foundation on which a Human Factors Analysis

Framework (HFAF) for the FRS can be established. To do so would make a significant contribution to error management and injury reduction in in not only English Fire and Rescue Services but also those of the devolved administrations of the UK. A synopsis of chapter content is provided in the thesis map that concludes this chapter.

The section that now follows adds ontological perspective by first explaining why the research focus is exclusive to English Fire and Rescue Services before providing a more general overview of the operational structures of the FRS. An additional closing section then explains through a reflective narrative the catalyst and motivation for undertaking this research.

1.2 Overview of the Operational Structures of the Fire and Rescue Service.

Along with England, Scotland, Wales and Northern Ireland, the Fire and Rescue Services (FRSs) of the United Kingdom include the Isle of Man and the Scilly Isles. Initial scrutiny of publicly available data relating to firefighter injury revealed that those published by the Department of Communities and Local Government (DCLG) of England were more complete. Consequently, the focus of this thesis is on the 45 FRSs of England which are largely based on Local Authority boundaries but also includes the jurisdiction of some Police and Crime Commissioners and those of the elected Mayors of London and the Greater Manchester Combined Authority.

The way in which these FRAs provide protection, prevention, and response services to the communities they serve is governed by the Fire and Rescue Services Act 2004. Recognising the growing demands faced by the FRS and need to focus resources on community risk the FRS Act ‘modernised’ the role of the FRS. FRAs now have a statutory duty to promote and encourage fire safety in their communities by providing and widely publicising fire safety messages. In addition to the more obvious duty to extinguish fires and protect life and property from fire, FRAs must also now make provision for dealing with Road

Traffic Accidents and other emergencies which includes significant environmental, man-made, and terror related incidents.

Modernisation of the FRS emerged from an independent review and resulted in fire safety education being delivered to school age children by FRSs throughout the country and the fitting of free domestic smoke alarms in tens of thousands of homes (Bain 2002). Soon after the FRS Act was implemented new Fire Safety legislation imposed a statutory responsibility on those responsible for business premises to carry out fire risk assessment, ensuring fire safety in almost all buildings (The Regulatory Reform (Fire Safety) Order 2005). Taking this modern risk-based approach, the combined effect of the new FRS Act and Fire Safety legislation had a significant impact on keeping society safe from fire when at home, at work, when taking leisure, and when visiting retail, commercial and industrial premises.

Modernisation also influenced the management structures of the FRS. A Competence framework based on a suite of National Occupational Standards (NOS) was introduced. NOS describes the knowledge, skills, personal qualities and attributes needed to perform safely and effectively. As employers, FRAs have a duty to ensure that firefighters and their commanders have the knowledge, skills and understanding to meet the demands of the emergency response domain where, when delivering public safety, firefighters face great risk. In this context, operational competence is core to the role of the FRS. Only when the competence standards of NOS can be applied effectively in the emergency response domain or be demonstrated in realistic simulations are individuals considered to be operationally competent (NOS 2021). With the development of NOS, a long established and compulsory theoretical and practical examination structure for the selection of supervisors and officers was discontinued. 12 levels of 'rank' were replaced by 'roles': Firefighter; Crew Manager; Watch Manager; Station Manager; Group Manager; Area Manager and Brigade Manager. Selection for 'development' at each role level has taken a different emphasis reflected in the new role titles, all but one, that of the firefighter, capturing the influence of the 'managerial' nature of their responsibility.

Modernisation also recognised that when on-duty, most operational fire service personnel were only spending 5 - 10% of their time responding to, attending, and dealing with incidents (Bain 2002:11). For fire station personnel time is now spent establishing, delivering, and maintaining fire safety education to the young, elderly, and vulnerable members of the many communities they serve. The effect of modernisation can be seen in Figure 1.1 which, until 2013, shows a continuous downward trend in incidents of almost 40 per cent.

Figure 1.1 Demonstrating reduction in the total number of incidents attended by FRSs in England following implementation of modernisation. (Taken from Home Office Fire Statistics Data Tables. Home Office 2021).

Figure 1.1 also demonstrates how, since 2014, the downward trend appears to have reversed and the total number of incidents increased only recently returning to the level of the year of data gathering for this research. This also corresponds with FRS budget provision being impacted by Government spending review which, by 2014 had resulted in a 22.5 per cent reduction in funding (LGA 2013:8). Such a dramatic reduction in funding demanded efficiency savings from FRAs. Inevitably this focused on staffing costs which represented 79% of fire service budgets (Knight 2013:23). Since 2014 this influenced several changes in operational response methodology as FRSs sought to maintain operational service provision.

Operational service provision is now based on the level of risk in the geographical area covered by a fire station where operational response is conditioned around two types of response availability. The continuous pattern of work which provides 24-hour availability across a variety of shift systems is generically described as the Whole-Time Duty System (WDS). An intermittent pattern of work based on part-time availability where responders have regular employment elsewhere responding only when needed, is described as the Retained Duty System (RDS).   A combined pattern of work also exists where continuous availability is provided at a fire station throughout the day but at evenings and weekends, in a similar way to RDS, WDS responders are 'On-call' from home. Depending on where they live, On-call responders may also provide cover at RDS fire stations which has led to the expression 'On-call' being embraced by retained duty system personnel as well.

To provide continuous 24-hour response, the WDS system is populated by a number of working groups referred to as watches. On-call provision will normally be populated by a single group or 'crew' of responders. Whether it be a watch or a crew there will be a single officer-in-charge (OiC) who in the role of Watch/Station Manager will be supported by one or more supervisory officers holding the role of Crew or Watch Manager who may also be responsible for an appliance and its crew. Collectively these roles are responsible for the administration, welfare, and training of an WDS watch or On-call crew. When dealing with an incident, the supervisor of the station or in the case of a small incident, an appliance, will normally assume the role of the Incident Commander (IC). Unlike fire station personnel, Station Managers up to Brigade Managers are conditioned to a Flexible Duty System (FDS) which, for operational response is based on an average of 78 hours availability per week a portion of which is also spent 'On-call' at home rather than on continuous duty.

The number of FDS, WDS and On-call responders has been in steady decline as FRS budgets have reduced (Table 1). Doing more with less is a common Public Sector mantra and reduced budgets have impacted recruitment. Natural wastage has resulted in staff at all levels not being replaced and reduced operational establishments (Table 1 indicates > 9,300 posts). The combined effect of a reduction in incidents shown in Figure 1.1; and a corresponding reduction in operational response staff being exposed to the hazards and risks of the emergency response domain; may explain why firefighter injury has reduced by a little over two thirds since the implementation of the modernisation agenda. However, the effects of modernisation have merged with the financial constraints and budget reductions of 2010 and from 2013 operational injuries were on the increase as was the general trend of incidents. Only in recent years have reported injuries reduced which once again, corresponds with a reduction in the number of incidents being attended (Table 1.1).

Table 1.1 The number of incidents, size of FRS operational establishments and number of reported operational injuries since the 2010 announcement of budget reductions (adapted from Home Office Fire Statistics Data Tables 2021).

	Incidents	Establishments	Reported Operational Injuries
2010/11	647,362	41,072	1229
2011/12	608,941	39,554	1220
2012/13	521,322	38,273	957
2013/14	526,895	36,950	1097
2014/15	496,275	35,700	1037
2015/16	529,674	34,128	1049
2016/17	560,689	32,524	1071
2017/18	571,930	32,002	1052
2018/19	576,533	31,995	1129
2019/20	558,013	31,912	963
2020/21	518,379	31,547	941

1.3 Reflection and Motivation.

On the evening of 6th April 2010 two firefighters entered a ninth floor flat in a residential high-rise building. A short time later they had both sustained fatal injuries. Given the serious nature of the circumstances, a police investigation was launched to determine if a criminal breach of responsibility had occurred. The researcher was one of the five strong team of managers, each with discrete professional specialisms who supported the police investigation. At the time of the investigation new health and safety guidance for fire authorities was published that would, for the first time, refer to the influence of Human Factors and the *"…individual characteristics that influence the behaviour of teams and individuals".* (DCLG 2013:32).

The joint police/fire service investigation was one of four conducted in parallel. The Health and Safety Executive (HSE); Fire Brigades' Union (FBU); and the FRS of the firefighters who lost their lives were also investigating the incident. The literature review of the following chapter describes how the unsafe act(s) of those involved can combine with a systemic causal history and produce such a tragic outcome (Reason 2016). For the firefighters involved in this case there were several such acts or omissions that could qualify for the description 'unsafe act'. However, there was one hypothesis that dominated thought and focused on a single such act.

The first two firefighters to enter the flat failed to locate a rapidly growing fire in the lounge. Despite having a thermal image camera with them, they chose not to use it to detect the heat source of the fire. Instead, they covered the light beams of their torches to see if additional darkness would reveal the glow of the fire. Still unable to detect the fire, based on experience, one of them decided the fire was likely to be upstairs in a bedroom. Both firefighters made their way upstairs to the first of two bedrooms. There they found no evidence of fire but to improve visibility and ease heat conditions they opened a window at ceiling height. Moving to the adjacent bedroom the circumstances were the same, no fire but heat and smoke. Once again, they opened a high-level window, an action known as ventilating (HFRS 2013). Now realising that they had missed the fire and it must still be downstairs in the lounge or kitchen they decided to go back downstairs.

At the top of the stairs, they were joined by two of their colleagues and tell them the fire must be back downstairs. Their colleagues had just climbed the stairs from the lounge and told them that it wasn't possible to get back down due to rapid fire development which made conditions unbearable. Despite this, the first team attempted to descend but halfway they had to quickly turn back aware that each flat had an alternative way out. In this case it was at a level further above the bedroom level.

Both firefighters were now feeling the effects of the sudden and rapid increase in temperature. The masks of their breathing apparatus were 'sooting' up and one of them was experiencing scalding of the hands through his protective gloves. They quickly made their way to the bedroom landing where they had recently spoken to their colleagues who were no longer present. Consequently, they assumed that they had already made good their exit. Not without some difficulty, they then quickly reached the fire exit and made good their escape.

Neither firefighter realised that the fire phenomenon that may have coincided with them opening high level windows above the fire had overwhelmed their colleagues soon after they left them at the top of the stairs when making their attempt to descend. As they successfully made their way to safety, they failed to notice their colleagues lying incapacitated, inside the open doorways of each bedroom.

This vignette is one of several that revealed a number of 'unsafe acts' that enabled accident-causing conditions. Each was pursued by the joint police/fire team, and each had a similar aetiology. The processes followed and the decisions made by those involved such as opening high level windows, made sense to them at the time. As investigation continued, many statements and descriptions of judgements, decisions, and choices revealed a reflexive theme: *"How often does a simple but erroneous act such as these result in injury; why does it make so much sense to those involved at the time"?*

This reflexive theme has been operationalised and becomes the foundation of the following three research questions also designed to meet the main aim and objectives described above, questions that this thesis now seeks to answer.

In response to the main aim and the 'critical decision making' aspect of the first objective of this research, the first research question seeks to not only explore the 'frequency' aspect of the operationalised theme but also examines a sample of reported injuries for additional frequency context relating to the demographic, temporal, environmental, and contextual preconditions of accident causation:

> Research Question 1 (RQ1) –
>
> How effective is the FRS at gathering, analysing, and understanding the pre-conditions and human factors of accident causation?

Exploring the 'erroneous act' and 'injury' components of the theme above, the second question acknowledges that on occasion firefighters will be working without the oversight of a supervisor or commander. When doing so they may be called upon to make a critical decision which may result in the deficit outcome of injury. This question uses the concept of error typing to more closely examine the unsafe aspect of the action that resulted in injury.

> Research Question 2 (RQ2) –
>
> When working without the oversight of a supervisor or commander firefighters may be called upon to make a 'critical decision'. When doing so, to what extent do they experience the deficit outcome of injury, and what type of active error is injury more likely to result from?

Fundamental to addressing the main aim and second objective of this research, understanding human factors is essential to improving error management in the FRS. Methods for capturing and analysing data relating to unsafe acts, their preconditions, supervisory and organisational influences are many and varied. This final research question examines the potential for developing a sector specific Human Factors Analysis Framework (HFAF).

> Research Question 3 (RQ3) –
>
> When developing targeted intervention strategies, how effective would a sector specific analysis tool be in supporting the FRS to better understand the active errors, their pre-conditions, and the supervisory and organisational influences of accident causation?

1.4 Thesis Map.

This research sets out to examine several factors that influence the decision making, actions and behaviours of firefighters when attending operational incidents which can result in either injury to themselves or other firefighters. By evaluating those factors that influence the situation awareness, judgements, decisions and behaviours of firefighters prior to and at the 'moment-of-choice'; the main aim of this research is to improve error management and contribute to injury reduction in the Fire and Rescue Service.

Chapter 1 – Introduction.

Identifies the experience that acted as catalyst to the research and provides a general picture of reporting firefighter injury in English Fire and Rescue Services (FRS). Provides a generic overview of the 'operational' emergency response structures of the FRS explaining how modernisation has resulted in a significant decrease in the emergency response demands of FRSs. Closes by describing the specific circumstances that prompted the research and how the activities of those involved revealed a dominant theme.

Thesis Contribution:

- Argues that despite a move to publication of fatal injury reports, there is a dearth of exploration of the human factors and preconditions that may have contributed to an unsafe act resulting in injury and offers substance to answering RQ1.
- Operationalises the dominant theme emerging from the reflexive experience to not only address the aim and objectives but also establish the research questions the thesis sets out to answer.
- The ontology of the research framework.

Chapter sub-headings:

Chapter Introduction

Overview of operational structures of the Fire and Rescue Service.

Refection and Motivation.

Thesis Map

Chapter 2 – Literature Review.

The literature is examined from three perspectives. The first explores frequency and explains why the focus is on English FRSs and data they are required to provide for an annual report. The second visits research on human error (HE) and the emergent 'architecture' used in its scientific scrutiny. The third explores the psychological mechanisms of decision and choice. Before closing the literature review considers those facets of judgement and decision making that form the foundation of the error management context of the FRS operational domain.

Thesis Contribution:

- Establishes the argument that annual FRS reporting data provides a minimum of information, is relatively inert and due to a lack of detail, opportunities for wider understanding of factors affecting the 'moment-of-choice' are limited.

- Examines the influence of context and based on the premise of human failure gives rise to the concept of ‘person-as-cause’ and exposes the view of the organisational and systemic accident paradigm and the concept of ‘person-as-barrier’.
- Examination of slips, lapses, mistakes, and violations makes an important contribution to development of an error typing taxonomy that establishes the Active Error Descriptors (AEDs) used as an analysis tool for closer scrutiny of reported FRS injury data of Study 1 and 2.
- Raises argument about the concept of competence and expertise and their relationship with reported firefighter injury.
- Offers understanding important to answering the Research Questions.

Chapter sub-headings:

Frequency of injury in the emergency response domain.

Human Error

Error.

Cognitive Performance.

The Significance of Context.

Understanding Accident Causation.

Accident Causation Terminology.

Defences and Person-as-Barrier.

Decision Making and Choice.

The Fire and Rescue Service ‘Error’ Management Context.

Chapter 3 – Methodology.

Describes how the mixed methods research approach uses a pragmatic philosophical positioning to examine factors affecting the ‘moment-of-choice’ of firefighters when they make a judgement, decision, and choice independently of their Incident Commander. Describes the research design and methods of the studies used to explore the human factors that may contribute to firefighter injury and whether their data are used effectively when FRSs are investigating, recording, analysing, and reporting accident causation.

The chapter explains how the intention to interview a selected group of injured parties identified in Study 1 who sustained injury during a ‘critical activity’ had to be revisited due to what is argued to be an example of risk aversion.

Thesis Contribution:

- Explains the research methodology used in seeking answers to the Research Questions.
- Argues for clarity in the way judgement and decision-making research of the fire sector misplaces the term ‘firefighter’ by using it as a generic term.
- Uses variables that represent the preconditions of accident causation such as the demographic, temporal, environmental and contextual characteristics, for the first time in the analysis of firefighter injury,
- Informing future research, the practical, and ethical constraints of exploring the relationship between human factors and firefighter injury in the ‘natural’ setting of fire service operations are explained.
- Uses a taxonomy of Active Error Descriptors (AEDs) as an ‘error typing’ variable in the data analysis.
- The epistemology of the research framework.

Chapter sub-headings:

Research Framework.

Context.

Research Design and Methods.

Chapter 4 – Study 1 Data Capture.

Uses data representing a sample on which valid judgements can be made, and focuses on the psychological pre-cursors, preconditions and HFs that in some way enable or influence the unsafe acts of firefighters and contribute to their injury. Data readily available to, acquired by, and known by all FRSs. The concept of Active Error Descriptors (AEDs) are used to identify if the unintended outcome of the 'moment-of-choice' could be attributed to a decision based; skill-based; or perception-based error; or a particular type of violation influenced by the preconditions existing at the time. Argues that the most powerful contextual cue that can influence the 'moment-of-choice' of firefighters is the expression 'persons reported'.

Thesis Contribution:

- Uses the 'error typing' taxonomy of Active Error Descriptors (AEDs) and argues for their adaptation as a component of an FRS HFAF.
- AEDs simplify the classification of unsafe acts for a cohort of participants that represent the FRS manager typically responsible for compiling injury data.
- Defines a 'critical activity' typical of dealing with 'persons reported' - *"circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome".*
- Makes an original and important contribution to research into firefighter safety in the emergency response domain and establishes the ability to inform the development of targeted injury reduction strategies for the FRS.
- Brings the relationship between reported operational injury and arrangements for the maintenance of competence worthy of closer scrutiny.
- Offers substance to answering RQ1.

Chapter sub-headings report results for analysis of:

Injury Profile.

Demographic profile and characteristics of Injured Parties (IPs).

Temporal preconditions.

Environmental preconditions.

Contextual preconditions.

Chapter 5 – Human Factors Analysis.

Explains the choice and describes the application of a taxonomy known as the Human Factors Analysis and Classification System (HFACS) (Weigmann and Shappell, 2003). Uses two case studies, and moderation following the first influences the development of a FRS sector specific version of the HFACS with the introduction of the FRS Safe Person Principles to the second case study (DCLG 2013). Using Krippendorff's Alpha (Kα) as the diagnostic measure, the way analysis was initially applied to each level of failure, and any sub-categories is explained in some detail. The rationale for applying percentage agreement as a comparator with the Kα results is also explained.

Thesis Contribution:

- The chapter serves to triangulate the use and application of AEDs and
- Explores the extent to which the judgement and agreements of a sample of the FRS managers participating in Study 1 could be considered reliable when using a specific Human Factors (HF) Analysis Tool.
- Since the introduction of HFACS many sector specific variants have been developed. The study examines the potential development and applicability of such a variant to the emergency response domain of the FRS that could be used as a component of an FRS HFAF.
- Provides further evidence raising concern about FRS arrangements for the maintenance of competence.
- Offers substance to answering RQ2.

Chapter sub-headings include:

Explanation of the moderation of the HFACS taxonomy.

Study 2 Analysis

Case Study 1 results.

Case study 2 results.

Summary of the application of a Human Factors analysis tool and potential for development of a sector specific version for the FRS.

Chapter 6 – Injured Party Experiences.

The chapter opens by reiterating how conducting semi-structured interviews with a meaningful portion of 93 specific reported injury cases identified in Study 1 was not possible and how the alternative of a questionnaire was instead adopted. Analysis of responses to an online questionnaire explores the environmental and contextual characteristics that influenced judgements, decisions, and actions at the 'moment-of-choice' and the utility of the chosen actions. Reveals that the presence or perceived presence of victims influences risk taking behaviour and argues that task fixation is more likely to occur when the emotional stressor Persons Reported is the dominant cue. The chapter establishes evidence of underreporting of injury and offers evidence that behaviour can be influenced by group culture and the risk of stigmatisation rather than risk of injury. Adding evidence to the competence debate participants in the role of firefighter provide evidence that their knowledge, skill and understanding was inadequate for the task at their 'moment-of-choice'.

Thesis Contribution:

- The study further explores the criticality of injured party choices resulting in injury. Several cases offer limited evidence of criticality and suggest that other preconditions influenced the unsafe act.
- Establishes evidence that when dealing with fires and implementing the requirements of an ICs tactical plan, firefighters are also critical decision makers.
- The study confirms that firefighters are experiencing the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander.

- Once again reveals the prominence of skill-based and decision-based errors revealed by the previous studies.
- Confirms that using an analysis tool such as the HFACS of Study 2 could reveal some other ‘factors’ involving unsafe acts, their preconditions as well as supervisory or organisational influences that could influence deficit outcomes.
- Triangulates the methodological approach of this research and informs the development of an FRS sector specific variant of the HFACS and development of an FRS Human Factors Analysis Framework (HFAF).
- Offers substance to answering RQ1 and RQ2.

Chapter sub-headings describe:

Questionnaire Construction.

Analysis.

Results including emotional; cultural; and experiential influences.

Summary of the analysis of injured party experiences and further evidence of the value of a sector specific analysis tool.

Chapter 7 General Discussion.

The chapter considers the findings, limitations, and strengths arising from the research and analysis of three studies used in what is argued to be the first data analysis undertaken by either the FRS or researchers of either the safety or judgement and decision-making sciences that specifically focuses on the judgements, decisions, and critical choices of firefighters as opposed to those of their ICs. Discusses how the three studies provide answers to the research questions above. Emphasises the value of Active Error Descriptors AEDs in quantifying the influence of decision-based; skill-based; or perception-based errors and violations. Argues for continued development of a UK FRS variant of the Human Factors Analysis and Classification System (HFACS) as a component of an effective FRS HFAF and offers discussion on its application to the FRS sector.

Thesis Contribution:

- Summarises strengths and limitations of research approach and signposts future research interest.
- Considers the effective use of Active Error Descriptors and their value in formulating targeted injury reduction intervention strategies.
- Stresses the value of a sector specific variant of the HFACS.
- Signposts the development of an FRS HFAF.
- Raises concern about FRS participation, the participation of injured parties, and the potential for underreporting of operational injury in any future research.

Chapter sub-headings consider:

Findings of Data Capture and Injured Party Experiences.

Findings arising from the Human Factors study and the use of the Human Factors Analysis and Classification System.

Limitations of the research design and approach.

Emergent Strengths of the Research.

Application to the Fire and Rescue Service.

Chapter 8 Conclusion.

In pursuit of the main aim and objectives of the research, the conclusion re-visits the research questions key findings and recommendations arising from its three studies. It claims that critical high risk – high benefit decisions are not exclusive to the domain of fireground commanders, and that the thesis reports the first examination of the influence of human factors (HF) on the critical choices of firefighters as opposed to the judgements, decisions, and choices of their supervisors and commanders. Subject to the endorsement of the National Fire Chiefs Council (NFCC) and the various representative bodies in support of the participation of FRSs and individuals alike, the conclusion also posits that any future research direction should take account of the strength and value in both academics and practitioners developing the studies of this research as three component parts of a holistic HFAF for the FRS.

2. LITERATURE REVIEW.

2.1 Introduction.

The reflection and motivation section that concludes the introduction above described how, the reflexive theme of this research emerged from the researchers experience of investigating the circumstances of two firefighter fatalities and the outcomes of several serious incident investigations. An unresolved and reflexive question about firefighter injuries established the theoretical perspectives, research framework and research questions explored by the literature review that follows. In support of the chosen research approach, several models, concepts and theories that can influence the 'moment-of-choice' of firefighters are examined that in turn influences the structure of three studies used to meet the aim and objectives described above.

The framework of a research approach lies in making epistemological and ontological assumptions explicit (Trafford and Leshem, 2012). Epistemology is concerned with *"what is (or should be) regarded as acceptable knowledge in a discipline"* (Bryman 2012 :27). The epistemology of the framework of this research is first visited here in the literature review. This is where the theory of knowledge and discovery of methods of validation of knowledge in relation to the understanding of accident causation and analysis (Grix, 2001:27) are explored from an historical and contemporary perspective.

In first pursuing the theory of knowledge, factors influencing the erroneous actions of firefighters, their outcomes, and how they make sense of the critical situations they encounter are approached from three perspectives. Setting the scene, the first perspective uses data provided by English Fire and Rescue Services (FRS) published annually in a national report (DCLG 2015, Home Office 2021).

This is followed by the second perspective which explores knowledge that directly contributes to answering research questions RQ1 and RQ2. Here, the literature review first visits research on human error and the emergent 'architecture' providing insight into the unintended outcomes of individual choice and action before considering the influence of context and developing argument advocating the concept of person-as-cause. The section that then follows further pursues this perspective by examining concepts, theories and models that aid understanding of erroneous acts. The concept of person-as-barrier is also explored before considering tools and techniques used in the analysis of unsafe acts that inform the construct of an error typing tool for use in the research studies designed to meet the aim and seek answers to the research questions of this research.

Further addressing RQ2 and RQ3, the third perspective reviews literature that explains the psychological mechanisms of decision and choice and the influence of expertise later used in discussion of competence. The final section of the literature review then considers those facets of judgement and decision making that form the foundation of the error management context of the FRS operational domain.

Ontology is concerned with the way the social world influences the behaviours, beliefs, and values of the actors within it (Bryman 2012 :6) and relates to the exploration of organisation and culture. The introduction of the previous chapter above (Section 1.2) establishes the ontology of the research framework where, predicated on the existence of organisations as complex socio-technical systems, an overview of the operational structures of the FRS is established. Adding to this ontology the final two sections of this literature review serve to further establish the *"nature of the social and political reality"* under investigation (Grix, 2001:138). Describing the social and cultural context *"…into which new recruits have to be socialised"* (Bryman 2012:6), the examination of FRS error management explores the contemporary approach taken by the FRS to develop the judgement and decision-making skills of incident commanders.

The literature review chapter then concludes by summarising the key issues that inform the methodology used to seek answers to the research questions of this thesis.

2.2 Frequency of Injury in the Emergency Response Domain.

Fundamental to understanding how effective the FRS is in gathering, analysing, and understanding the pre-conditions and human factors of accident causation (RQ1), injuries sustained by FRS staff whilst at work are reported annually to the government department responsible for FRS matters. At the time of commencing this research this was the Department for Communities and Local Government (DCLG). Their 'Fire and Rescue Authorities' Operational Statistics Bulletin for England reported data for injuries sustained during operational incidents, training activities and during routine activities (DCLG 2015). These data are summarised from a national perspective, and each is reported separately on an accompanying data sheet. In January 2017 responsibility for FRS matters transferred from the DCLG to the Home Office. The annual FRS report is now published under a new title as part of the 'Fire and rescue workforce and pensions statistics' (Home Office 2021).

Only headline data relating to injury sustained during operational incidents as provided by FRSs in England is reported for three main categories: (a) the total number of personnel injured; (b) severity of injury; and relating to severity, (c) whether injury resulted in fatality. Reporting of severity is based on criteria found in the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR). RIDDOR only requires FRSs to record injuries that result in a three day absence from work although, without exception, and important to answering RQ1 and RQ2, all reported injuries are recorded and investigated by FRSs. Where injury results in absence of seven or more days or where the injured party is taken directly to hospital and in cases of fatal injury, FRSs must also formally report the circumstances to the UK Health and Safety Executive (HSE).

Also relevant to the aim and objectives of this research, RIDDOR applies to injuries resulting from identifiable but unintended events such as being hit by a falling object. More specifically, RIDDOR relates to injuries that occur due to the way work was being carried out or, because of the plant, machinery, equipment, or substances being used at the time. RIDDOR also applies where the condition of the site or premises where the injury occurred played a significant role. Consequently, the RIDDOR criteria will apply in the case of most, if not all, reportable injuries sustained by firefighters in the emergency response domain (The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013).

In addition to demonstrating severity the annual FRS report (Home Office 2021) separates data into two categories indicating whether injury is associated with firefighting activity or when dealing with a 'special service' which is the general description used for non-fire incidents. Table 2.1 demonstrates these categories and their column headers as contained in the annual Home Office data report and shows the total count for each category in the current ten year period (Home Office, 2021).

Table 2.1 Demonstrating Column Headers of Annual Home Office Injury Reports. Adapted from Home Office Fire Statistics Table 0508b (Home Office 2021).

Reporting Period	Total		Reportable Injuries*		Major Injuries		Fatalities	
	Fires	Non-Fire	Fires	Non-Fire	Fires	Non-Fire	Fires	Non-Fire
11/12	966	254	183	45	19	2	0	0
12/13	656	301	105	58	20	11	0	0
13/14	733	364	129	77	27	8	1	0
14/15	743	294	158	65	24	9	0	0
15/16	693	356	142	85	11	5	1	0
16/17	717	354	142	68	51	24	0	0
17/18	741	311	130	34	22	6	0	0
18/19	806	323	123	41	21	7	0	0
19/20	655	308	91	39	14	9	0	0
20/21	631	310	89	40	4	6	0	0
Total	7341	3175	1292	552	213	87	2	0

** The qualifying period for reportable injuries was three days until the 2017 reporting period when it was adjusted to seven days by amendment to the RIDDOR Regulations.*

In terms of frequency, the data sheet provides a minimum of information, and providing the rationale for the phrase 'emergency response domain', includes injuries sustained from the moment personnel are responding to, in attendance at, and when returning from an incident (Home Office 2021). The annual report from which they are taken includes a chart that demonstrates the total number of injuries for the period 2002-2021 (Figure 2.1).

Figure 2.1 Total injuries to firefighters by generic activity sustained in FRSs in England; 2002/03 to 2020/21as depicted in national reports (Home Office 2021).

Whilst demonstrating frequency based on a total count of the headline data categories reported annually, the data provided are basic and relatively inert. The published data of Figure 2.1 would indicate that since 2014 they have reached a plateau ≈1034 reported operational injuries per year posited in the notes of the 2019 annual report: *"since 2014/15 the number of injuries had plateaued…then decreased slightly in 2019/20".* (Home Office 2020:13). Although the section of the Home Office report where these data can be found is headed 'Firefighter's health and safety' (Home Office 2021:15), due to lack of detail, opportunities for learning are limited and offer little understanding of factors affecting the 'moment-of-choice' of those involved.

However, when providing the information on which the annual statistics report is based, FRSs have to provide data relating to severity of injury and therefore in most, if not all cases would have conducted post-hoc accident investigation. Depending on injury severity, investigations would have explored the demographic, environmental and contextual preconditions that would in some way, have influenced the choices made by those involved. This is an important source of context not only relevant to answering RQ1 but arguably invaluable to intervention and injury reduction strategies. In the case of the more severe accidents, a detailed investigation and analysis narrative report with outcomes and recommendations is produced. These reports are occasionally shared with other FRSs when they are no longer sub judice. Those that are shared are often made publicly available via online access. Their narratives capture some of the detail required of RIDDOR but do not include many of the identifiable environmental and contextual factors that influence the unsafe actions of those involved sought by RQ2. Human factors that can influence the 'moment-of-choice' are not explained in a way that they may lead to improved understanding of their influence on accident and injury.

As evidenced above the year-on-year reduction of injury in the emergency response domain of the FRS has recently reached a plateau (Figure 2.1), and that reductions depicted in the earlier years of this century are largely due to a corresponding reduction in incident activity rather than any 'overt' intervention strategy adopted by the FRS. The basic nature of the data published by the Home Office does not improve understanding, and opportunities for the FRS to establish organisational learning are limited to a handful of intermittently published reports. Despite this, all FRSs maintain data relating to the demographic, temporal, contextual and environmental conditions that influence human behaviours at the 'moment-of-choice'.

The section that follows reveals a general acceptance that people at the point of delivery, those at the sharp end of organisational activities, can and do make mistakes, that 'human error is inevitable' and the human operator can be expected to err (Harris and Simpson 2016, Johnson et al 2013, POST 2001). So much so that, contemporary sector specific FRS research accepts that human error is a major causal factor in accidents at work (Butler, Honey and Cohen-Hatton 2019).

2.3 Human Error.

Adopting a focus on human error is often associated with binary language: responsibility and accountability, right and wrong, good and bad, fault and blame, making it inseparable from the concept of human failure and giving rise to the expression used in this literature review of person-as-cause. The associated binary language also leads to difficulty in definition Hollnagel (1983) argues that human error is not an observable activity and instead *"characterizes the outcome of an action rather than the cause"* (Hollnagel 1983 :1). Whittingham (2004) advocates human error to be: *"…an unintended failure of a purposeful action, either singly or as part of a planned sequence of actions, to achieve an intended outcome…"* (Whittingham 2004:6). Arguing that human error could not be an activity that leads to an outcome, Hollnagel (1993) posits that the term human error is a 'misuse of terminology'. He instead prefers 'erroneous action' which he defines as *"an action which fails to produce the expected result which therefore leads to an unwanted consequence"* (Hollnagel, 1993 :67). However, the literature discusses common components that involve an intention, an action, and an unintended outcome (Dekker 2015, Hollnagel 1993, 2014, Leveson 2011, Whittingham 2004), Understanding their role in firefighter injury is important to the aim of this research and can be used to explore the concept of person-as-cause and inform response to RQ2.

Erroneous action is also described as 'active failure' (Reason 1990, 1997, 2016), which supports the notion of person-as-cause and originates from the analysis of unsafe acts of workers and the influence of their ability to operate safely. Original theorising saw accident prevention as a matter of common sense that should focus on mitigating the influences of the direct causes, acts, and conditions immediately preceding an accident (Heinrich 1941). The attribution of 'human error' to those most closely involved with unintended outcomes, is typified by more contemporary theorising as the period when aircraft accidents were likely to be associated with 'pilot error' (Sharit 2012).

Errors occurring from the unintended actions of individuals are variously categorised as 'action slips'; 'active failures' and 'latent failures' (Heinrich 1941, Norman 1981, Plant and Stanton 2012, Reason 1990, 1997, 2016). Expressions such as these are part of the enduring architecture of error that pervades the literature. Their origins lie in accident causation research that followed several major industrial and transportation accidents occurring during or before the 1980's, a period described as the decade of disaster (Larrabee 2000). Important to the design of the research methodology described below, this contemporary architecture is examined here as three descriptive groups relating to: error; cognitive performance; and those with contextual significance.

2.3.1 Error.

Error descriptors are a group of terms used in the literature that define and attempt to describe the nature of slips, lapses, mistakes, and violations (Ali et al 2016, HSE 2012, Klockner and Hicks 2015, Reason 1997, 2008, 2016, Sharit 2012). Whilst they are arguably also cognitive in nature, here they are treated as a separate descriptive group.

Slips –

The descriptor 'slip' has long been associated with error (Norman 1981, Reason 1990). Slips are known to occur when there are several possible choices of action and represent failure in the execution or commission of action. They are perceived to be a powerful source of data for analysing the influence of the components of intention and chosen action.

Lapse –

The expression lapse is a term derived from research into memory and recall characterised by the common phrase 'lapse of memory' (Ali et al 2016, HSE 2012, Klockner and Hicks 2015). Ali et al (2016) describe lapse as a 'mental slip' and posit that they occur where "*intention is correct*" (Ali et al 2016:1267). Also known as errors of omission, lapses often involve missing a step in a sequence which is known to occur under conditions of time pressure, which is a feature of the emergency response domain of the FRS, associated with human error (Ali et al 2016, Amyotte and Khan 2005:67, Embrey (nd), Sharit 2012).

Slips and lapses are commonly associated with atypical behaviour in the performance of familiar or routine actions carried out in a familiar environment. They are provoked by inattention, distraction, or change in either the immediate surroundings or the planned course of action which are also circumstances common to the emergency response domain of the FRS (Stichting 2014, Ali et al 2012, Li 2016). Representing failure to achieve an expected outcome, slips and lapses are collectively described as mistakes.

Mistakes –

Reason (1990) argues that mistakes constitute a far greater danger because at the time, those involved think they are doing the right thing. Mistakes are often due to a lack of knowledge, where the planned choice of action and implementation go entirely as intended but prove to be inadequate. They are known to be harder for the operator to detect at the time they occur. They occur more frequently in circumstances where task demands rely on operator judgement and decision making when problem solving or dealing with the unexpected (Isaac et al 2002, Santiago 2007, Shappell and Weigmann 2000, Sutcliffe, Shin and Gregoriades 2002, Zhang, Polet and Vanderhaegen 2002).

Violations –

Unlike a mistake where behaviour is unintended, violations represent an inherent intention not to follow system requirements – 'the rules'. They are likely to occur when working conditions are not as expected and not completely understood and occasionally represent new and unpractised procedural adaptation. When dealing with similar circumstances, the FRS describes such adaptation as the application of 'Operational Discretion'. Violations are frequently committed by those at the sharp end of work activity (Reason 2006:29). They are representative of crossing or breaching safety barriers in the form of rules, procedures, guidance, and regulations designed to *"…reduce the degree of liberty…"* of operators (Polet, Vanderhaegan, and Wieringa, 2002:178). By weakening system defences designed to provide a safe working environment, those involved are exposed to risks from which they are normally protected, increasing the potential for accident and injury (Polet, Vanderhaegan, and Wieringa, 2002; Reason 2006; Zhang, Polet, and Vanderhaegen 2002).

Polet, Vanderhaegan and Wieringa (2002) explain how barrier crossing (violation) occurs following a situation assessment that should consider time, resource, and effort of the activity; the benefit to be gained from the activity; and any potential deficit that may occur should barrier crossing behaviour create an unsafe situation, all of which are also components of the FRS practice of Operational Discretion. Because violations can take those involved into areas of greater risk they are described as potentially the most unforgiving and dangerous of error causing behaviours. Those involved may not fully appreciate the risks involved and fail to take adequate protective measures (Reason, 1997)

When balancing risk against potential benefit to be gained from violation, if risks are not fully appreciated, particularly when faced with novel or unfamiliar circumstances, the level of risk may be unacceptable. Therefore, risk perception should be central to concerns about violations: *"People have to be aware of a hazard before they can make a judgement as to the associated risks to themselves and others"* (Santiago, 2007:31).

Circumstances that lead to violations conceal complex causal factors. Violating behaviours are governed by a motivational framework, social context, organisational and systemic factors such as training, management and supervision, equipment design, and cultural components that can influence the potential for violation all of which are common to the emergency response domain of the FRS (Keith and Frese 2008, Reason 1995). Violations fall broadly into three categories: a) routine violations - normal or automatic behaviours or 'work arounds' used to cope with rules/procedures; b) situational violations - influenced by the immediate workspace or environment; and c) exceptional violations which are rare and more likely to occur in exceptional or emergency situations such as when firefighters are performing a rescue (Dekker 2015).

2.3.2 Cognitive Performance.

The relationship between rules, violations, and procedural adaptation based on the balance of risk and benefit infers a more demanding need for processing information which occurs on three levels of cognitive performance (Rasmussen 1983, Griggs 2012, Sharit 2012). Further adding to the architecture of error, these levels are described as Skill-based, Rule-based, and Knowledge-based behaviours.

Skill Based –

Influenced by environmental or contextual cues, skill-based behaviours are associated with highly practiced routines, processes, patterns of activity and actions. By-passing working memory, this is smooth automated ‘hardwired’ behaviour exercised without conscious control, requiring little cognitive effort that follows the intention to act (Christensen, Sutton and McIlwain 2016, Griggs 2012, Mitchell, Williamson, and Molesworth 2016, Rasmussen 1983, Sharit 2012).

Rule Based –

At this level of cognitive performance, memory; trained procedures; and previous experiences are more influential. This is where explicit know-how stored in working memory, often based on the use of ‘if A occurs then do B’ rules or schemas to achieve the intended goal. The pattern matching characteristics of long-term memory are also influential at this level of cognitive performance (Griggs 2012, Reason 2016, Sharit 2012).

Knowledge Based –

A higher level of performance and demand on cognitive resources, the knowledge based level, is heavily dependent on long term memory, diagnosis, and analysis skills for success. Knowledge based tasks are more likely to be those where rules stored in memory are not being effective, where a solution is not immediately apparent or where circumstances are new and unfamiliar to those involved. Actions are devised by physical testing or ‘trial and error’, or a process of ‘mental modelling’. Whilst performance is controlled by the intended goal, the end state is also dependent on skilled based actions (Rasmussen 1983, Salazar 2001, Sharit 2012).

Circumstances where a solution is not immediately apparent or is new and therefore unfamiliar typify the way in which context contributes to the inevitability of an unsafe act. Contextual circumstances are known to influence behaviours and place operators at the mercy of cognitive and situational factors thus adding contextual significance to the architecture of error.

2.3.3 Contextual Significance.

It is generally accepted that erroneous behaviour is affected by the context in which it occurs (Leveson 2017, Norman and Smith 1995, Rasmussen 1997). Described as performance shaping, the causal factors of accidents arising from error, are found within this broad context where Dekker argues the organisational world *"lays the groundwork for errors"* and the operational world *"allows them to spin into larger trouble"* (Dekker 2006:119). Influential to the design of Study 3 described below (see Chapter 6), the literature places great emphasis on the need to take context into account, strongly arguing that an unsafe act or 'active failure' at the sharp end is but the start point for understanding error the key to which will be found in 'upstream' activities (Dekker 2006, Reason 1997, 2016, Woods et al 2010, Yoon, Ham and Yoon 2016), However, implicitly, this also transfers responsibility and the propensity for unsafe acts 'upstream' by creating an *"illusion of management responsibilities for all errors"* (Difford 2011, Young et al 2004, 2005).

The upstream focus identified above describes organisational and systemic failings as inevitable and, in some cases, normal. Their contribution to accident causation is characterised with the label of 'latent conditions' (Harris and Simpson 2016, Horsky, Zhang and Pattel 2005, Leveson 2011, Perrow 1999, Reason 1997, 2016). This notion of inevitability and normality implicitly places those at the sharp end in the role of enablers of accidents waiting to happen, performing *"normal work and responding to the work context in reasonable, even skilful ways"* (Sharit 2012:735).

Giving rise to the concept of person-as-cause used in this literature review, the focus on the contribution and influence of latent conditions to unsafe acts at the sharp end is arguably a catalyst to the most contentious of all debates found in the literature - the very existence and influence of human failings at the sharp-end ‘moment-of-choice’. (Dekker 2006, 2007, 2015, Difford 2011, Young et al 2004, 2005).

Difford (2011) explores the extent to which the person (or people) directly involved with active errors at the ‘moment-of-choice’ are in some way responsible and accountable for their own actions. Difford argues that if accident and injury cannot occur without an unsafe act, focussing accident prevention on failure at the sharp end is a matter of *“undeniable logic”* (Difford 2011:12). It is this preposition that RQ2 examines by focussing on person-as-cause and also factors influencing intended action at the ‘moment-of-choice’ and is arguably unavoidable. Also relevant to RQ2, planned action or the intention of the operator when achieving a task, the means of achieving it, and the environment in which it is conducted has a direct relationship with the occurrence of active errors (Reason 2016, Whittingham 2004).

The context of the operational environment of the FRS emergency response domain is variously described as emotionally charged, rapidly changing, information limited, and time constrained (Ash & Smallman 2010, Flin, O’Connor & Crichton 2008, Klein, Calderwood & Clinton-Cirocco 2010, Nemeth & Klein 2010, Mishra, Allen & Pearman 2015, Rahman 2009). What so many of these treaties omit from their litany of theories is that it is also fundamentally unsafe. For those present, unlike the safe workplace of the socio-technological environment and organisational and systemic context that becomes unsafe resulting in a major industrial, nuclear or transport accident. The raison d’être of the firefighter is to intentionally enter and confront unsafe conditions. Conditions in which some will put themselves in harm’s way to mitigate the effects of the unsafe acts of others. Although, not done recklessly, there are few comparisons that can be drawn to this arguably unsafe behaviour. For the firefighter, it can also be described as normal work where although intentional, the firefighter also responds ‘*to the work context in reasonable, even skilful ways’* (Sharit 2012:735).

Summarising this section of the literature review, it can be concluded that labelling the actions of the sharp end operator as human error is contentious. To do so focuses more on outcome than cause. There are many environmental and contextual characteristics that impinge on the ability of firefighters to operate safely. Therefore, whilst the concept of person-as-cause embraces the unintended sharp end active error and unsafe act it should not solely be defined by the erroneous behaviour of those involved at the 'moment-of-choice'. It should also focus on the environmental and contextual preconditions that influence such behaviour. The architecture of error described above has emerged from the desire to better understand human involvement in accident causation and in meeting the aim of this research informs answers to the first two research questions above (see page 13) and is further examined in the section that follows.

2.4 Understanding Accident Causation.

The body of knowledge from which current understanding of accident causation and analysis has emerged is represented by many 'milestone' theories and models such as Organisational accident theory (Orgax) (Reason 2016); Normal accident theory (Perrow 1999); the theory of High Reliability Organisations (Rochlin, La Porte and Roberts 1987); and Systems theory (Leveson 2008). Their origins are long established and have passed through decades of scientific scrutiny.

Some organisations operating in environments with a high hazard and accident potential report low accident and error rates and generally high safety performance. They are described in the literature as High Reliability Organisations (HROs). The HRO literature (Bourrier 2011, Dekker and Woods 2010, Lekka 2011, Leveson 2015, Rochlin, La Porte and Roberts 1987, Sutcliffe 2011, Weick, Sutcliffe, and Obstfeld 2005), strongly argues that safety is something that organisations do, not something they have, and looks closely at what can be done by people to successfully manage risks. Their foundation lies in a 'cultural' approach to safety.

In the FRS context, there is quite some synergy with the organisational principles of HROs. HROs provide a crucial service to society, and they have 'nested authority structures' where rules and standard operating procedures are designed to maximise operational predictability. At times of greatest pressure, such as in the emergency response domain, authority shifts downwards where a supervisor in the role of an incident commander or even a firefighter working remotely can have considerable decision-making discretion and accountability (Bourrier 2011, Hopkins 1999).

Systems theorists variously describe the components that comprise a system, including human operators, as 'mere parts' of a system (Perrow 1999:66) but treating humans in this way deflects from interest in human motivation at the sharp end (Hopkins 1999). They argue that conclusions drawn by HRO researchers are limited in their usefulness and argue that HRO theories 'oversimplify' the causes of accidents and underestimate the problems associated with uncertainty (Marais, Dulac, and Leveson 2004:11). This polarised view offers an alternative systems approach to safety where the focus is instead on the relationship between the technical, organisational, and social aspects, favouring top-down systems thinking rather than the bottom up reliability engineering of HROs.

Shifting the research focus from person-as-cause to person-as-barrier, the emergence of systems theory resulted from increasing complexity in the interactions between people, technology, and their operating environment (Underwood and Waterson 2013b). Systems theory endeavours to analyse the way these different components and processes act together when exposed to different and unanticipated influences. The basic concept is that of control, where achieving system safety requires constraints to limit the behaviour or control the interaction of system components (including people in the system), organisational structures, engineering, design, social structures, and physical components (Dekker 2006, 2011, Leveson 2008, 2015).

A more contemporary systems theory view argues that explaining accidents in terms of simple or complex cause and effect relationships is *“no longer a valid approach to the management of system safety”* (Hollnagel 2014:125). Hollnagel’s central argument is that instead of maintaining a focus on how things go wrong, systems theorists and analysts should give greater if not dominant importance to the ways in which they are going right (Hollnagel 2014:175, Woods et al 2010).

Despite this contemporary view, learning from success continues to receive less attention in the literature than learning from accidents (Rosness et al 2016). However, the pendulum has nevertheless swung away from person-as-cause and blaming sharp-end individual(s) for active errors. Instead, human involvement in error is viewed from an organisational perspective where defence against system hazards should provide barriers to prevent Orgax (Reason 1997, 2016). The upstream focus instead being on an organisations system, where the latent conditions that contribute or in some way influence unsafe acts at the sharp end are to be found.

A significant source of criticism of this upstream view comes from accident investigation practitioners. So much so that the Institute of Industrial Accident Investigators have devoted a whole volume to ‘redressing the balance’ (Difford 2011). Difford (2011) strongly asserts the view of person-as-cause and dismisses the notion that all organisational accidents originate in upstream latent conditions. It can be argued that in doing so, Difford fails to recognise the value Orgax holds as a framework that without complexity, can focus the attention of analysts and investigators on not only the active failures but also latent upstream failings in their pursuit of causation. In contrast, whilst also critical, Young et al (2004, 2005) acknowledge the revolutionary effect the SCM has had on accident investigation, how it has put human factors ‘on the map’, and following accidents, recommendations arising from scrutiny of upstream latent conditions have undoubtedly improved the management of both health, and safety in organisations (Young et al 2004, 2005).

The more dominant theories in the literature on which understanding of accident causation has been established are synthesised into a consolidated taxonomy (Table 2.2). The taxonomy demonstrates how focus on the individual was subsumed by Orgax. Emergent and contemporary accident causation, investigation and analysis tools and techniques are in turn identified and aligned to the original analysis theorising that strongly influenced their design. In different ways each addresses individual involvement in active errors, latent errors within the organisation, and system influences that go beyond an organisation into a wider environment. However, whilst their locus of interest is on accidents as undesirable outcomes, important to seeking an answer to RQ2 and RQ3 few specifically examine human factors that can be associated with injury.

2.5 Accident Causation Terminology.

In pursuing the main aim of this research, examining the literature for research and theorising of ‘injury theory’ it was found that the lexicon of accident causation contains little evidence of empirical research categorically known as 'injury theory'. The terms accident and injury are used synonymously in the literature and injury and accident causation research largely overlaps (Khanzode, Maiti and Ray 2012).

Definitions of an accident also vary throughout the literature. For example, Perrow’s definition (1999:64) captures *“unintended damage to people and objects”.* Hollnagel (2004:5) refers to *“a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome…and must directly or indirectly be the result of human activity”,* and Leveson (2011:467) describes *“an undesired and unplanned event that results in loss (including loss of human life or injury…)”.* From these definitions, the emergent components that are of particular interest in meeting the aims and objectives of this research are: temporal - they are sudden and arguably unexpected; and human - they will directly or indirectly result from human activity and be undesirable to, and unwanted by those present and may or may not injure them. In contrast, definitions of injury consistently describe the harmful human effects of an accident sequence.

Just as the semantics of accident and injury vary in definition based on the discipline or paradigm of study, so too does the use and application of terms an injury causing ‘event’ or ‘incident’. Exposing yet more polarised opinion, some scholars (Gnoni and Lettera 2012; Saleh et al 2010; Strauch 2004), infer a sequential hierarchy where, as precursors, errors lead to events and either separately or combine as several events that accumulate and lead to an accident. However, using the expression 'incidents without adverse consequences' Kessels-Habraken et al (2010) and Drupsteen, Groeneweg, and Zwetsloot (2013) oppose the concept of hierarchical severity.

Systems theory draws distinction between the expressions event and incident taking account of the extent or severity of damage to property, production, or people. Here events that only cause damage to part of a system are described as incidents. Whereas accidents are described as events that damage an entire system (Perrow 1999).

In meeting the aims and objectives of this research, seeking answers to the research questions, and further contributing to the ontology and in pursuit of contextual clarity and given the organisation that forms the locus of interest of this thesis, it is important to place the expression ‘incident’ in its organisational and grounded cultural context. The term incident is used throughout the Fire and Rescue Service (FRS) and arguably the ‘emergency services’ to describe the topographical environment arising from the circumstances of an event regardless of its severity. For example, as the consequence of an event, the scene of an incident may spread beyond its immediate proximity. An incident will vary in size and complexity and require differing resources to mitigate the effects of an event. Important to the process of mitigation is the organisation of resources under a single unified management system. In the FRS, this is the Incident Command System, and a single person will establish responsibility over the largely temporary organisation assembled to reduce and/or mitigate the effects of an incident. The title s/he will adopt for that role is that of 'Incident Commander'. With incidents given this organisational context it is equally important to provide semantic clarity to the remaining terms of the accident and injury lexicon.

The terms used in this thesis for accident, injury, and event can also be better placed into the FRS environmental context. As identified above, other than the physical elements, there are two primary components to accident definition temporal and human. Representing the events stage of accident propagation, the combination of the temporal and physical components may result in physical damage but not necessarily human injury. However, the primary focus of this thesis being firefighter (operator) injury it is also helpful to maintain a clear distinction between those events that cause injury and those that do not. Therefore, for clarity in future discussion, circumstances where no injury results from an event, sequence or chain of events during emergency response operations are described as a 'near miss'. Circumstances where injury does occur are described as an accident.

Table 2.2 A simple consolidated taxonomy of dominant methods/models including emergent accident causation, investigation and analysis tools and techniques.

Focus of Interest	Originator	Circa	Dominant Theory	Emergent, models tools and techniques
Individual	Heinrich	1939	Domino Model	Loss Causation Model (Bird and Germaine)
Organisation	Rasmussen	1979	Model of the level of cognitive functioning Skill Rule Knowledge Behaviours	Generic Error Modelling System (GEMS) Accident Map (AcciMAP)
	Reason	1990 1997	Generic Error Modelling System Swiss Cheese Model of Defences	Generic Error Modelling System (GEMS) TRIPOD + variants Human Factors Analysis and Classification System (HFACS)
System	Hollnagel	1998	System Failure - within complex socio-technic systems	Cognitive Reliability and Error Assessment Method (CREAM) Functional Resonance Analysis Method (FRAM)
	Dekker	2007	Human involvement in system failure	None Associated
	Leveson	2004	Application of systems thinking to safety	Systems-Theoretic Accident Model and Processes (STAMP).

The change in focus from person-as-cause and blaming an individual for active errors, examines human error from an organisational perspective where defence against system hazards should provide barriers to prevent Orgax. In seeking answers to the questions of this research (RQ1 – RQ3), this relationship between system defences, barriers and accident causation is considered in the following section which explores the potential alternate concept of person-as-barrier.

2.6 Defences, Barriers, and Person-as-Barrier.

Defences include features of a safety system that compensate for the potential of human failures. They also account for uncertainties in human performance (Flin et al 2000, Reason 1997, Saleh et al 2010).

Their fundamental operating principle lies in the insertion of layers of defence designed to obstruct the emergence and progress of accident causing conditions and avoid the need for reliance on a single element or component (Bakolas and Saleh 2011, Janssens et al 2015, Saleh et al 2010). The term safety barrier describes the variety of technical and procedural ways the concept of defence-in-depth achieves the objective of preventing, containing, or mitigating accident causing conditions (Hayes 2012, Saleh et al 2010, Saleh et al 2014, Sklet 2006). The rules of an organisation that rely on the knowledge of their user to achieve their purpose such as the Standard Operating Procedures (SOPs) of a FRS are just such a barrier. They are amongst the ‘soft’ barriers that rely heavily on the combination of paper and the behaviours of people.

Barriers function as the constraints that reduce the degree of liberty of operators to degrade or violate their protection which is described above as ‘barrier crossing’. Although barrier crossing is only labelled a violation when it could have been avoided, the outcome or judgement of cost, benefit and deficit are the driving forces of barrier crossing behaviour and in the guise of risk assessment, inherent in the emergency response domain of the FRS. Intentional barrier crossing can involve an operator adapting (violating) the SOP operating procedure, where there can be an immediate benefit that outweighs the cost of violation, a concept described as exercising Operational Discretion by the FRS (see Section 2.3.1 below). But representing person-as-cause, where barrier crossing exposes the operator to hazardous or dangerous conditions there could be an undesired outcome described as a deficit (Polet, Vanderhaegan and Wieringa 2002).

There are many ways in which barrier crossing or violation can occur or combine: deficient regulatory oversight; system design and technical flaws; organisational behaviours; management shortcomings, and operational or workforce failings. Each of which underpin how the human system component can produce accident causing conditions or act as person-as-cause. However, so too do they represent opportunities for human involvement in system control or the role of person-as-barrier. The involvement of 'people' as barriers operating at different levels within organisations changes in nature from the origins of management strategy and policy to the operator's application of an operational decision at the sharp end where accidents are often said to be the result of inadequate control (Saleh et al 2010, Leveson 2011:67).

The enormity of the consequences of inadequate control enabling person-as-cause has been experienced in nuclear energy production (Three Mile Island 1979 (Woods et al, 2010)); petro-chemical processing (Buncefield 2005, Newton, 2008)); industrial manufacturing (Rana Plaza 2013 (BBC 2013); and transportation (Costa Concordia 2012 (Vogt 2017)). At the point where the barriers of such complex high technology systems fail, society's last line of defence or mitigation is to implement the resilience arrangements of emergency response. When prevention measures and barriers have failed to separate victims from hazards, when warnings or alarms fail to alert them; where safety features are unable to render a system safe; when *"all of these prior defences fail, then escape and* *rescue measures are brought into play"* (Reason 1997:7). This is also when the defence-in-depth and barriers found in the preparedness, procedures and people of the FRS 'system' are called upon.

For the FRS, as a physical means of preventing, controlling, or mitigating undesired events or accidents (Sklet 2006), the human operator – the firefighter, becomes the last physical barrier in the safety defences of a complex high reliability organisation. Here adequacy, suitability or success supports the principle of person-as-barrier. Inadequacy or deficit measured in near misses, and albeit infrequently, reported accidents to firefighters represent the transition in their performance mode from person-as-barrier to person-as-cause. However, the antithesis of person-as-barrier posits that, rather than a barrier that acts upon and/or within a system, human involvement should be viewed as a 'boundary' that exists independently or 'outside the system' (Difford 2011),

> *"Something that can opt to decide not to function as intended cannot possibly be a barrier. The alternative is to consider a system wherein one barrier is knowingly (and uncontrollably) capable of damaging another".*
> (Difford 2011:156).

System safety afforded by defence-in-depth can be compromised by the flawed decisions of operators (Bakolas and Saleh 2011). The cause of barrier crossing and violation or performance mode transition from person-as-barrier to person-as-cause is influenced by the way people make sense of their situation at the 'moment-of-choice' – the preconditions of context and influence of intention. This sensemaking process - how decisions are made, is inextricably linked to accident causation. Important to answering research questions RQ1 and RQ2, understanding how the psychological mechanisms of decision making and choice can impinge on the safety of firefighters is significant to the aim of this research and provides the focus of the following section.

2.7 Decision Making and Choice.

Important to seeking an answer to RQ2, this section explores the way decision makers 'make sense' of their situations, a process characterised as sensemaking (Klein 2009) and described as a continuous process used to order reality, reduce ambiguity, and manage the unexpected, sensemaking "...*serves as a springboard into action."* (Weick, Sutcliffe and Obstfeld 2005:409). Weick offers the basic idea that *"reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs"* (Weick 1993:635); and for Klein *"sensemaking is not just a matter of joining the dots,...sensemaking determines what counts as a dot"* (Klein 2009:127).

Sensemaking is seen to be an important part of decision making also described as Situation Awareness (SA) (Hutton, Klein and Wiggins 2008; Sarna 2002; Weick, Sutcliffe and Obstfeld 2005). However, Weick himself applies a more pragmatic description and asserts that there should be no attempt to interpret its meaning. He argues that sensemaking is to be understood literally, "*sensemaking is what it says it is, namely, making something sensible"* (Weick 1995:16), and he applies it to unexpected and ambiguous conditions, common features of the natural setting of the emergency response domain of the FRS.

Understanding how people make decisions in a 'natural' setting gave rise to a new paradigm in the science of judgement and decision making. Described as naturalistic decision making (NDM) this new paradigm emerged in 1989 (Zsambok 1997) and largely concentrates on problem solving strategies in natural settings such as the emergency response domain of the FRS. The characteristics of the natural setting of interest to NDM researchers involves high risk, uncertainty, and complexity where information on which decisions are made is ambiguous, dynamic, volatile, uncertain, and often time constrained (Flin et al 1997, Flin and Arbuthnot 2002, Flin, O'Connor, and Crichton 2008, Pruitt, Cannon-Bowers and Salas 1997, Zsambok and Klein 1997).

The main objective of NDM research lies in improving the outcomes of decision making by analysing the processes adopted by skilled decision makers, *"those more skilled at recognising situations developed through experience"* and the way they use their experience(s) (Klein, Calderwood and Clinton-Cirocco 2010:198). Differing propositions of NDM demonstrate consistency in the way they are influenced by several key elements: the dynamic nature of decision making; assessment of the situation; the influence of mental imagery; recognition described as pattern matching; and more recently, the influence of intuition (Flin et al 1997; Flin, O'Connor and Crichton 2008, Endsley and Garland 2008, Endsley and Jones 2012, Hardman 2009, Klein 2015, Pruit, Cannon-Bowers and Salas 1997).

The NDM model which has had the greatest influence on the emergency response domain of the FRS is largely based on 'observations of fire ground commanders' originated by Klein, Calderwood and Clinton-Cirocco (2010). Their original research set out to address what they saw as a gap in decision making research - the temporal influence of time pressure on the decision-making process (Klein, Calderwood and Clinton-Cirocco 2010, Nemeth and Klein 2010). Rather than scrutinise and analyse deliberative decision-making processes they chose instead to study the *"tactical decisions made at the scene of a fire by Fireground Commanders"* (Klein, Calderwood and Clinton-Cirocco 2010:1). The choice of fire ground commanders as participants was influenced by the dynamics of the incident situations they experienced where *"tactical and strategic decisions must frequently be made under extreme time pressure".* Particularly when attending fires where their decisions were *"frequently measured in seconds"* (Klein, Calderwood and Clinton-Cirocco 2010:1).

The expectation of Klein's original study was that participants would reflect a classical approach by describing their more troublesome decisions as a comparison of alternative options. (Klein, Calderwood and Clinton-Cirocco 2010:193). The major finding was that consideration of an alternative was rare, option selection was not occurring in the time pressured environment of the experienced fire ground commanders in the study. It was found that decisions depended on their recognition of situations similar to those 'merged in memory' where, guided by a prototype experience (previously experienced incident), a course of action was being selected without alternative options being considered. This cognitive process was characterised by Klein et al as 'Recognition Primed Decision-making' (RPD) (Figure 2.2).

In the process of RPD there is a simple pattern recognition match where a decision maker recognises a situation as *"typical and familiar"* and understands which "*goals make sense*" and which environmental *"cues are important".* These familiar *"action scripts"* mean they not only know what to expect next, but they also know how to respond and the *"course of action likely to succeed"* (Klein 2004:22). Where patterns are not familiar, options are generated by a process of imagining or *"playing through in the mind"* or *"mental simulation".* If a solution is offered, it is applied, but where necessary, as in trial and error, a near solution is altered to improve it (Klein 2009:90).

In their original seminal work Klein, Calderwood and Clinton Cirocco (2010) also created a new momentum in the debate on the role of situational awareness (SA). They described how, in the process of evaluating and generating a choice of action, the time taken to reach SA is *"the most important aspect"* of a decision (Klein, Calderwood, and Clinton-Cirocco 2010:204).

As a foundation for decision making and performance SA is said to apply to *"almost every field of endeavour"* (Endsley and Jones, 2012). Whilst the individual elements of SA are domain specific, the application of SA to the emergency response domain of the FRS is, as with RPD, widely accepted (Cohen-Hatton, Butler and Honey 2015, Edgar et al 2012, Flin, O'Connor and Crichton 2008, Flin and Arbuthnot 2002). SA is a state of knowledge about a dynamic environment and constitutes a critical focal point and precursor of the decision-making process. The most widely accepted, cited and applied model of SA is that of Endsley (Endsley 1995, Flin, O'Connor and Crichton 2008).

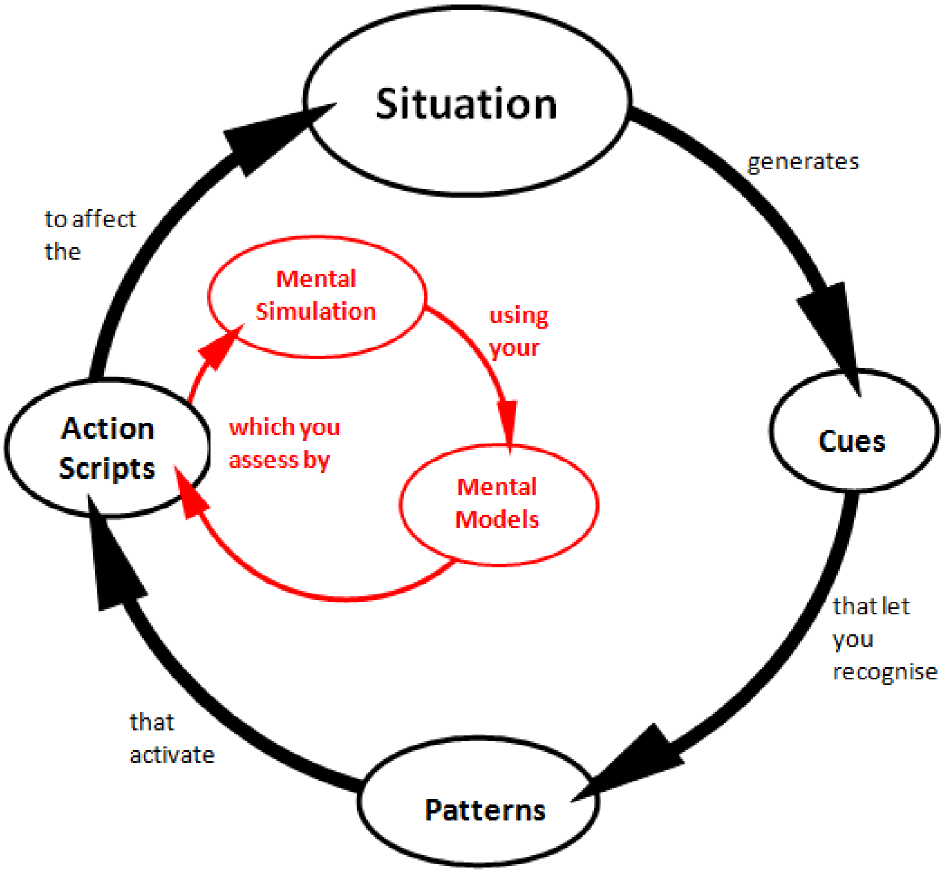

Figure 2.2 The Contemporary version of the Recognition Primed Decision Model adapted from Klein 2009.

Endsley describes SA simply as *"being aware of what is happening around you and understanding what the information means to you now and in the future"* (Endsley and Jones 2012:13). In its simplest form Endsley distils SA into three levels: Level 1 being the perception of the elements in the environment; Level 2 comprehension of the current situation; and Level 3 projection to the expected future state of the environment (Endsley and Jones 2012:14) (Figure 2.3). Golightly et al (2010) paraphrase these levels as: What? So what? And what next? Flin, O'Connor and Crichton (2008) also offer a simplified explanation of the processes as *"knowing what is going on around you'"* (Flin, O'Connor and Crichton 2008:17).

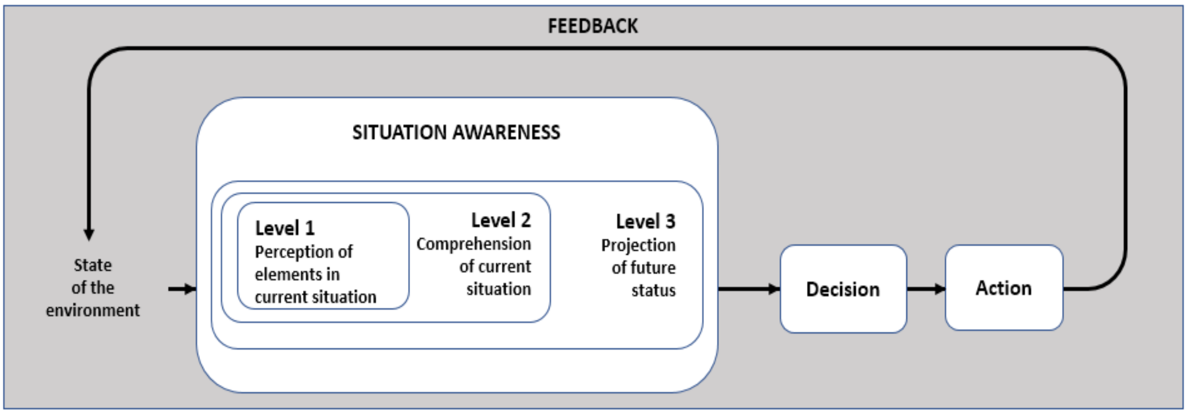

Figure 2.3 Simple model of Situation Awareness in dynamic decision making, adapted from Endsley 1995.

To draw a distinction between sensemaking and SA Endsley (2015) reflects the 'retrospective' view of Weick (1993) and describes sensemaking as diagnostic and backward looking, forming reasons for past events. This sensemaking approach and situation assessment are captured at the comprehension level of awareness (Level 1), SA focuses the way this knowledge influences the situation at the time (Level 2) and the future state; the projection level (Level 3). Endsley argues that in this way SA provides a fuller understanding of a situation which implies a more informed decision and action, with a higher likelihood of optimum performance. Wickens (2008) sees SA as a system of understanding, and distinct from action or performance, suggesting that *"good SA is generally necessary but not sufficient for good performance"* (Wickens 2008:398).

Relevant to research of the emergency response domain of the FRS, Wickens (2008) argues that SA is only applicable in dynamic situations where change occurs in seconds or minutes and not synonymous with the 'time construct' of long-term memory (Wickens 2008). However, literature review reveals that the basic cognitive structures on which SA is based include attention, perception, short term sensory memory, working memory, and long-term memory (Endsley 1995, 2012, Endsley and Garland 2008). All of which have a significant bearing on RPD and the ability to recall from memory, prototypical experiences, and compile schemas, action scripts and mental models. The synergy between sensemaking and RPD and the way they rely on the 'schemata' of past experiences to provide structure to the current situation is also recognised by researchers of the emergency response domain of the FRS (Okoli, Watt and Weller 2017). However, absolute reliability on RPD and associated 'intuitive' processes is subject to scientific challenge in the literature.

Despite considerable published empirical research on the role and application of intuition in decision making (Bearman and Bremner 2013, Dane, Rockmann and Platt 2012, Flach 2015, Klein 2004, Klein, Calderwood and Clinton-Cirocco 2010, Nemeth and Klein 2010, Sadler-Smith 2016), the literature continues to suggest a lack of consensus about the circumstances where intuition is appropriate (Dane, Rockmann and Platt 2012, Sadler-Smith 2016).

Lack of agreement lies in the difficulty some researchers of the classical (normalistic) decision making paradigm have in accepting what they describe as vague evidence on which the NDM paradigm bases its RPD and intuitive decision-making theorising. The normalistic paradigm favours research evidence derived from the deliberative choice demonstrated in controlled laboratory experiments. Whereas the NDM experiment focuses on the way research participants can remember, recognise and describe patterns from previously encountered experiences and compare them with environmental cues in their natural environment (Dane, Rockmann and Pratt 2012, Kahneman and Klein 2009, March 1994, Okoli and Watt 2018, Reiman and Rollenhagen 2011, Sadler-Smith 2016).

Klein defines intuition as *"the way we translate our experiences into action"* and argues that intuition is *"a natural and direct outgrowth of experience"* (Klein 2004, page Hiv), and that *"a* *psychology of judgement and decision making that ignores intuitive skills is seriously blinkered"* (Klein 2015, page 166).

The role of intuition in judgement and decision making is not only the point of contention between the normalistic and naturalistic, but also where both paradigms converge. This convergence sits between the analytical and deliberative choice research of the laboratory and the rapid choice theories of the real world NDM setting such as RPD. Convergence is represented by the influence of heuristics and biases on judgements and choices made under conditions of uncertainty. (Gigerenzer and Todd 1999, Gilovich, Griffin and Kahneman 2007, Kahneman, Slovic and Tversky 2006, Kahneman and Klein 2009, Kahneman 2003).

The most prolific and prominent research into the relationship of heuristics and biases on intuitive judgements and decision is that of psychologists Tversky and Kahneman (1974, 1981, 1986). Their research into poor performance associated with intuitive judgements revealed that some responses came to mind more easily than others and it was possible to distinguish between the cognitive processes behind this unique difference (Kahneman 2003, Tversky and Kahneman 1974, 1981, 1986). This difference is described as System 1 and System 2 reasoning where System 1 thinking uses less 'reasoning' than System 2 (Stanovich and West 2000, Kahneman 2003).

The intuitive judgements of System 1 occur automatically and require less cognitive effort. Not only important in response to RQ2, but also influential to the analysis of Study 3 intuitive judgements are influenced by emotions and recognition of experiences. Judgement, choice, and action is reached with cognitive ease, information is processed quickly and is often associated with impulse. More deliberate and effortful, System 2 is invoked when the outcomes of System 1 are not as expected. Associated with working memory, the more deliberate, effortful and analytical reasoning of System 2 processes information more slowly, compares options and is often knowledge based invoking organisational rules and procedures.

The successful outcomes of System 1 thinking also have an important association with individual skill. Kahneman argues that skill comes with regular practice, analysis, and reflective feedback on the application of thoughts and actions. When these requirements of skill acquisition have been fulfilled the *"judgements and choices that quickly come to mind will mostly be accurate"* (Kahneman 2011:416). Here further synergy exists with the rapid and effortless performance of heuristics in the way SA and RPD also recognise the influence of expertise derived from sustained application of skills.

This performance issue is revealed in the discussion of expert decision making offered by Johnson (2014), who explains how study of judgement and decision making in High Reliability Organisations relied heavily on experience and the intuitive processes of RPD. Limitations in skill and experience resulted in a more deliberate and analytical decision-making strategy being adopted to avoid the *"potential impact of critical human errors"* (Johnson 2014:40).

This difference of decision performance between novices and experts is a consistent feature of both the normalistic and naturalistic paradigm. Words such as expertise, expert and experience are used to invoke the proposition that the judgements and decisions of the more experienced, skilled and knowledgeable decision maker are applied more rapidly and effectively than those of the less experienced novice. It is this argument that leads researchers of the NDM paradigm to seek ways of strengthening intuition by learning from experts and the use of simulation, creating a wider repertoire of tacit knowledge, cues and mental models that broaden experience and achieve better decisions (Dane, Rockman and Pratt 2012, Kahneman and Klein 2009, Perry et al 2012, Ackerman 2014). Evidence of the convergence of both paradigms lies in their jointly held view that judgements and decisions are influenced by experience(s) and those "*of a rookie firefighter would be far less accurate than those used by a commander with 20 years of practice*" (Flin et al 1997:13, Klein, Calderwood and Clinton-Cirocco 2010). However, Klein posits that *"intuition is not infallible"*, that experience can sometimes be misleading and result in mistakes (Klein 1999:34).

The literature establishes a relationship between experience and the ability to make sense of the unexpected, often ambiguous, high risk and time constrained environment of the emergency response domain of the FRS. The focus on skilled decision makers and the way they use their experience to establish situation awareness and recognise environmental cues, rapidly analyse meaning and select a course of action is firmly established in the emergency response domain of the FRS. Experience and intuition are inextricably linked by both the normalistic and naturalistic schools of thought both of which acknowledge the importance of the acquisition of skill which comes with experience. The relationship between novice and experts examined under the guise of experience and competence in the FRS is considered in the following section which explores the 'error' management context of the emergency response domain of the FRS.

2.8 The Fire and Rescue Service 'Error' Management Context.

An important contribution to the aim of this research, framing of answers to RQ1 and RQ2, and adding ontological substance, this penultimate section examines the Fire and Rescue Service (FRS) error management context from the perspective of the psychological precursors and preconditions of the emergency response domain that impact on the firefighters 'moment-of-choice'. Arguably it is these that have the most direct influence on 'active failures', and transition from the performance mode of person-as-barrier to person-as-cause, and result in injury causing accidents. Every year, for 30 of the individuals involved the effects can be far reaching and long lasting (see Table 2.1 above).

The incident environment of the emergency response domain has been previously identified as emotionally charged, rapidly changing, information limited and time constrained (Ash & Smallman 2010, Flin, O'Connor & Crichton 2008, Klein, Calderwood & Clinton-Cirocco 2010, Nemeth & Klein 2010, Mishra, Allen & Pearman 2015, Rahman 2009). Here it is also argued that when acting in the performance mode of person-as-barrier, entering the unsafe conditions of an incident, although intentional, is not done recklessly. The decision to do so is the product of a judgement and decision-making process and, as previously described, a single person known as the Incident Commander (IC) will establish responsibility over the largely temporary organisation assembled to mitigate the effects of an incident.

For firefighters in the UK to have an officer physically leading when inside a building on fire is uncommon. It is more common for commanders to exercise remote supervision and behavioural control. Initially this would be based on incomplete situation awareness resulting in a verbal task briefing which, often would be remotely supervised via radio communications. Assumption of skill, knowledge, and competence of those entering this environment is the norm.

Such remote supervision is more common to incidents involving the entry of firefighters in Self Contained Breathing Apparatus (SCBA) for search, rescue, and firefighting. Of the 14 firefighter fatalities that have occurred during firefighting operations since the turn of the century, 12 have involved firefighters undertaking search, rescue and firefighting operations wearing SCBA (two such incidents are later used as case studies in Study 2 of this research). Recent research into the impact of SCBA tasks on the cognition, physiology, and coping strategies of firefighters found that not only the physical demand of firefighting when wearing SCBA is a frequent source of stress but that firefighters experience cognitive stress from knowing an incorrect decision can result in personal injury (active injury) or injure another member of the team (passive injury), and influence performance mode transition (Young et al, 2014).

In the case of non-fire incidents such as road traffic collisions (RTCs), industrial accidents, water, and animal rescue, it is likely that an IC or subordinate commanders appointed by an IC will have proximal oversight and control of task activity. These are collaborative working environments and in some instances such as the extrication of victims trapped in vehicles following RTC, involve well practiced task activity. However, the IC would exercise close supervision, maintain SA throughout and have ownership and control of critical decision-making. The contextual circumstances of many non-fire incidents are indicative of the 'novel' situation and with only 30 per cent of incidents attended by the FRS in England being non-fires, experienced less frequently (Home Office 2021).

Therefore, for firefighters in England (and throughout the UK), when implementing the requirements of the ICs tactical plan, in considering RQ2 it is important to acknowledge that, it is more likely for unsupervised firefighters to be acting under their own judgement and decision making in fires than in non-fire incidents. In doing so, it is more likely they will encounter unexpected and unforeseen circumstances. They will also experience the physical and emotional stressors of dealing with what is described as 'persons reported', and either actively or passively, the immediate consequences of an 'unsafe act' not of their own making.

Regardless of an incident type, at any stage of emergency response, when it is known that lives are in danger, 'persons reported' is the expression commonly used by the FRS to indicate the presence of victims. This is whether it be known at the time of initial response, through information gained during response, or information first made known upon attendance and an initial situation assessment. As a psychological precursor, the expression 'persons reported' adds to the intensity of the stimuli or event (Rahman 2007), and in turn can invoke an emotional response in those responding. The consequences of erroneous decision-making and knowledge of the potential consequences for persons trapped by fire is a significant cognitive stressor. Rahman describes such a high stakes environment as being in 'non-equilibrium' and argues that this is an environment where knowledge and understanding of human behaviour and performance is limited (Catino and Patriotta 2013, Rahman 2007; Young et al 2014).

The FRS provides a suite of National Operational Guidance (NOG) on the processes an IC should adopt for the safe resolution of an incident. When dealing with 'persons reported', this establishes the expectation that no matter what the incident context may be *"where lives are in danger and the benefit of saving life is high, then a higher risk to firefighters may be accepted"* (NOG 2021g). However, this guidance establishes the need for a balance to be struck between ensuring firefighter safety and meeting societies demands for safety imposed by the Fire and Rescue Service Act 2004. The FRS characterises this balance in what is described as the Firefighter Safety Maxim.

> *"At every incident the greater the potential benefit of fire and rescue actions, the greater the risk that is accepted by commanders and firefighters. Activities that present a high risk to safety are limited to those that have the potential to save life or to prevent rapid and significant escalation of the incident."*
>
> National Operational Guidance (NOG 2021g)

Despite the research of the Naturalistic Decision Making (NDM) paradigm into judgement and decision-making providing evidence of the sometimes-critical influence that emotions can have, the subject has received little attention from behavioural decision researchers. A recent systematic literature review examined decision-making, risk and coping and found little scientific literature examining the emotional demands experienced by firefighters in the emergency response domain (Rhys-Evans, 2019). The NDM paradigm is also opaque on the issue of emotional influence on decision outcomes. (Rahman 2007, 2009; Mosier and Fischer 2010). Rahman has attempted to close the knowledge gap with a framework of High Velocity Human Factors (HVHF) but concedes that research into cognition under stress *"has not delved deep into decision making when danger is imminent"* (Rahman 2009:1).

In circumstances of 'persons reported', where life is immediately at risk, characterising the rapidly changing, and time constrained environment, decisions are intuitive and rapid. So too are they likely to be based on incomplete information, have a strong emotional influence, and based on a balance of risk and benefit, involve acceptance of high levels of risk (Cohen-Hatton & Honey 2015; NOG 2021b). Where environmental conditions do not strongly present 'threat to life' the judgement and decision-making context is less intuitive and more analytical. These are the conditions of Martin, Flin and Skriver's (1997), 'continuum of decision strategies', where at one end of the continuum the characteristics of time constraints and risk level invoke intuitive decisions. But when the environment is in a steadier state, at the other end of the continuum analytical strategies involving option and choice are exercised (Figure 2.4), (Martin, Flin and Skriver 1997).

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Figure 2.4 A decision making continuum demonstrating the transition from intuitive to analytical decision making. Taken from NOG (2021b).

Representative System 2 reasoning, this also explains the degree of conscious control exercised by a decision maker as captured by Rasmussen's skill, rule and knowledge classification of cognitive processing (Rasmussen 1983). When a novice encounters a decision or an experienced decision maker a novel situation beyond their tacit knowledge or skill there is a need to acquire new knowledge. In these circumstances, situation assessment and search for information requires considerable mental effort and reflective monitoring of actions which impacts the cognitive resource demand. Where the circumstances are familiar and actions are practiced as in System 1 reasoning, the skill-based response requires little conscious effort and cognitive resources (Stanovich and West 2000, Kahneman 2003). Rule based processing lies as an intermediary between these two levels.

These aspects of the judgement and decision making of ICs are a frequently researched phenomenon of the NDM paradigm (Ash and Smallman 2010). However, originating with the work of Klein (Klein, Calderwood and Clinton-Cirocco 2010), the research literature describing studies of ‘firefighters’ is misleading and uses the term firefighter generically to describe both commanders and the firefighters they lead during the process of firefighting. Only under analysis is it possible to determine that most studies hold a significant bias towards the judgement and decision-making expertise and repertoire of ICs (Bearman & Bremner, 2013; Calderwood, Crandall & Klein, 1987; Cohen-Hatton, Butler & Honey, 2015; Cohen-Hatton & Honey, 2015; Glick-Smith, 2011; Lamb, et al 2014; Launder & Perry, 2014; Okoli et al, 2016).

This is an important distinction to establish as whilst an IC is responsible for leading the incident to a successful conclusion, they are not responsible for making all decisions or supervising every detail of an incident. Some actions and task requirements are instead communicated to those who will implement them which will often involve firefighters working remotely who are often the first to encounter the unknown or unexpected and sometimes critical incident developments. (Cohen-Hatton, Butler, and Honey 2015). Whilst studies of the decision-making behaviours and performance of ICs are prolific, here it is argued that specific study of the decision-making behaviours and performance of the firefighters designated to achieve the operational tactics and physical actions of an IC’s plan are atypical and represent a gap in knowledge.

NOG is explicit in the need for FRSs to ensure that people selected for performing command functions can do so and can demonstrate clear potential to deal with stressful situations where there is sustained pressure. Once appointed, they should receive the training and development that prepares them for the complex decision-making environments they will encounter. ICs must acquire the operational knowledge and understanding needed to resolve the range of incidents that are reasonably foreseeable and adapt to those that are not. In doing so FRSs should ensure that incident commanders are periodically required to demonstrate competence in their role and have sufficient time and facilities to practise the skills they need for command (NOG 2021j).

Essential to the performance mode of person-as-barrier, competence in the emergency response domain requires both firefighters and their commanders to have the skills, knowledge and understanding to perform their duties effectively. They are considered operationally competent when they have demonstrated those abilities in either real situations or during realistic simulation. A national suite of core operational skills and corresponding requisite knowledge sets the standard against which both the initial acquisition and ongoing maintenance of effective performance and competence is measured (NOS 2021).

The ability to undertake responsibilities and to perform activities to a recognised standard on a regular or ongoing basis is also an expectation of the UK Health and Safety Executive (HSE). However, the HSE not only adds the dimension of experience when describing competence but also includes attitude, physical ability and thinking skills (HSE 2018). In addition to being able to perform competently, the FRS holds an expectation that, *“where there may be limited controls over hazards and risks”,* an individual will also perform as a safe person (DCLG 2013:29). Important to the performance mode of person-as-barrier, the individual responsibilities to being a safe person include self-awareness; being observant and constantly aware of a situation; being decisive about hazard and risk mitigation and communicating circumstances of hazard and risk that may be unknown or unexpected by others . In setting those individual responsibilities, the FRS acknowledges that some of the key elements of the mode of person-as-barrier and being a safe person are built on behaviours developed with experience (DCLG:29).

The expectation that to be safe, firefighters should be decisive about hazard and risk and where necessary *"…mitigate risk by taking action to reduce personal and team exposure to risk…"* (DCLG 2013), assumes they are adequately able and have been prepared to do so. The debate on judgement and decision making of section 2.7 above links the experience and intuition of 'commanders' with the ability to make sense of circumstances of hazard and risk. It places great emphasis on the influence of their expertise in decision-making. Whilst acknowledging that the judgements and decisions of a "rookie firefighter" are less accurate than a well-practised commander there is no acknowledgement that the bias is on improving the decision-making of novice commanders. (Flin et al 1997; Flin and Arbuthnot 2002; Flin, O'Connor, and Crichton 2008; Klein, Calderwood and Clinton-Cirocco 2010; Klein 2015).

Risk taking by both firefighters and their commanders throughout UK FRSs is subject to the influence of the Firefighters Safety Maxim (the maxim) above. The maxim establishes boundaries for both the risk appetite of commanders and risk-taking behaviour of firefighters based on the level of risk accepted when deciding on barrier crossing behaviours or violations (Polet, Vanderhaegan and Wieringa, 2002).

Key to satisfying the expectations established by the maxim in the uncertainty of the dynamics of the emergency response domain is the largely intuitive and crucial cognitive and arguably heuristic process known as Dynamic Risk Assessment (DRA). This is where the nature of risk is quickly determined, and reasonably practicable measures are taken to manage it (NOG 2021d). This further links the risk-taking behaviour of firefighters with their ability to make what are sometimes critical decisions.

The current FRS iteration of DRA describes it as a continuous process that, considering risk and benefit, is used for quickly determining the nature of and initial response to hazards and risk. Its initial inflection is directed at 'the person undertaking the assessment' (NOG 2021d) but then describes the process as a sequence of considerations, judgements, and actions for an IC. NOG also describes DRA as an initial assessment that forms the basis of Analytical Risk Assessment (ARA) (NOG 2021a). Although responsibility for carrying out an ARA may be delegated by the IC to a subordinate commander, NOG avoids inferring that this more detailed risk assessment and resulting decision-making can be carried out by firefighters.

Given the circumstances of its rapid application it is argued that DRA can also be described as an intuitive cognitive process. However, the NOG position on intuitive decision making is dichotomous. Not only does it discourage intuitive decision-making warning how it can lead to decision traps which are described as *"…an errant thought process that can lead to an incorrect decision being made…"* (NOG 2021b), NOG also posits that decision traps are pitfalls associated with intuitive decision-making (NOG 2021e).

Despite which, NOG also acknowledges research of the NDM paradigm when describing how the development of mental models can *"…subsequently underpin skills such as intuitive decision-making, which research has shown to be used greatly in an on-scene environment"* (NOG 2021i). Recent NDM research has also shown that *"… the ability to effectively conduct dynamic risk assessment on the fireground lies in utilising existing knowledge, which is largely rooted in experience"* and further argues that when utilising knowledge gained through experience, experienced decision-makers employ intuitive decision-making as a default strategy (Okoli et al 2016:19, Okoli and Watt, 2018).

NOG guidance on intuitive decision making does not specifically include the role of firefighter, reference is instead made throughout to commanders or on one occasion 'decision makers'. NOG does however acknowledge that *"A great deal of decision-making occurs on the incident ground, from operational personnel to those with commanding roles",* and that *"decision-making processes and traps apply to all decision makers on the incident ground".* Despite which NOG exclusively directs ICs to consider decision controls to avoid decision traps (NOG 2021b).

The decision controls process (DCP) assimilates with the risk assessment responsibility of an IC and involves four stages commencing with a situation assessment and establishing situation awareness before formulating a plan of action. Wherever possible, the process then calls for consideration and exercise of decision controls which are described as a *"rapid mental check that the decision is appropriate and safe"* (NOG 2021b,c) before an IC implements any command decisions. The DCP also describes how ICs should continuously actively monitor incident developments to ensure they are meeting expectations (see Figure 2.5), (Cohen-Hatton, Butler, and Honey 2015; NOG 2021b).

NOG describes decision traps as a cognitive process that can lead to a situation going wrong (NOG 2021e). Examples are symbiotic to inadequate situation assessment and incorrect or incomplete situational awareness and include circumstances when a decision is made on the basis of incomplete knowledge of the situation, such as a cue or a goal and not the overall picture; or when a decision is based on the wrong interpretation of the situation any of which can lead to transition to person-as-cause (NOG 2021b, e). Whilst recognising the role of RPD and how it can be useful when operating in familiar situations NOG recommends ICs to be cautious as the situation may not be as imagined (NOG 2021h). Throughout what is arguably biased content on decision traps or the DCP, NOG avoids reference to deficit of understanding arising from lack of competence, knowledge, skill, experience instead referring to them as hazards.

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Figure 2.5 The Decision Control Process. Taken from NOG (2021b).

The bias of NOG is toward the critical decision-making challenges faced by an IC and makes occasional mention of 'decision maker' and 'personnel' without specifically capturing the role of the firefighter. Guidance identified as personal or individual risk assessment is directed at the role of firefighter and relates to the risk assessment responsibility and process that helps firefighters perform in the mode of person-as-barrier and remain safe when working unsupervised, (DCLG 2013, NOG 2021f). Complemented by the individual responsibilities of being a safe person, this guidance is directed at the role of firefighter and describes the process they should undertake to *"identify hazards and determine the level of risk they will accept"* when they encounter unexpected or unforeseen situations (DCLG 2013:23). However, Okoli et al are clear in their assertion that *"… the ability to effectively conduct dynamic risk assessment on the fireground lies in utilising existing knowledge,* *which is largely rooted in experience"* (Okoli et al 2016:19). Klein also argues that intuition, described by NOG as rapid, reflexive and relatively automatic is *"a natural and direct outgrowth of experience"* (Klein 2004: Hiv).

Experience and *"the ways in which people make sense of the things they encounter"* (Paloniemi 2006:440), are inherent to the development of competence. Bridging knowledge and skill, practical and tacit experience is irreplaceable and cannot be learned through education. Competence is not only manifest in practical skill and influential to the process of decision-making, for the firefighter it is significantly influenced by, and refreshed in context-dependent practical situations and heavily reliant on exposure to the challenges and demands of incidents encountered in the emergency response domain (Paloniemi 2006).

Figure 2.6 indicates how the total number of fire incidents attended since the impact of the modernisation agenda (Bain 2002) has reduced by almost 56% and the number of non-fire incidents by almost 42%. This represents a significant reduction in opportunities for ICs to experience the challenges of incident command and decision making of the 'natural' environment. This has led to a growing concern for the effect of 'skill fade' on judgement and decision-making performance (Lamb, Davies and Bowley 2014). The FRS has over a corresponding period sought innovative ways to replicate the experience gained from operational incidents. Incident command skills such as communication, effective use of resources and information, and formulation of strategy are common to both simulated and actual incidents (CFOA 2015, Lamb, et al 2014).

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Figure 2.7. Indicating the reduction in fires and non-fires since the advent of the Modernisation agenda. (Taken from Home Office Fire Statistics Data Tables 2021).

Simulation in the form of scenario-based exercising has been and continues to be extensively used as both a means of gaining and maintaining experience; demonstrating competence; and the assessment of judgement and decision making of ICs. In recent years, there has been an emergence of simulation technology. Initially, in the form of computer based interactive scenario's to more recent developments of total immersion and virtual reality 'suites' that can simulate a total incident environment and enable interaction with a command support infrastructure where actions directly impact the situation. (Vidal, Harbour and Jorda 2011). Skriver (1998) posited that these costly and elaborate infrastructures provide *"the best means for observing decision making in action in a controllable situation"* and offer an effective means of assessing what people do in real life and the effects on cognition and decision making (Skriver 1998:78).

However, there are many differences between simulation and reality (CFOA 2015) the time pressures, resource constraints and high stakes of real-world incidents are not easily reproduced (Lamb et al 2014; Orasanu and Connolly 1993). Cohen-Hatton and Honey have argued that the level of actual risk, uncertainty, and moral pressures are not adequately explored in simulation (Cohen-Hatton and Honey 2015). Researchers also believe the ‘limited realism’ of simulation limits experimentation. (Grote and Zala-Mezo 2002). A study conducted by the Chief Fire Officers Association (CFOA) found that ICs demonstrated *“more evidence of planning”* in the virtual environment than the more realistic contexts (CFOA 2015, page 23). More importantly, the bias of this focus and investment in resource and infrastructure is once again to develop and assess the judgement and decision-making performance of incident commanders. As with decision-making discussed above, this ‘commander’ centric approach can be seen in many contemporary studies of judgement and decision making. (Bearman & Bremner 2013; Cohen-Hatton, Butler & Honey 2015; Cohen-Hatton & Honey 2015; Glick-Smith 2011; Lamb et al 2014; Launder & Perry 2014)

NOG offers guidance on replacing lost experience and practical learning and although no less relevant to firefighters, in each case the narrative is directed towards *“complementing real command experience”* (NOG 2021i), and the development of *“skills incident commanders must demonstrate to be safe and effective when in charge”* (NOG 2021j). The actual guidance offered identifies techniques that are equally applicable to the role of firefighter such as in the case of lectures; use of case studies; exercising; simulations; role play; and tactical decision-making exercises. In each case no mention is made of the role of firefighter and when navigating NOG, the entire narrative on compensating for reduced opportunity for incident experience and comprehending situation awareness is biased toward the role of incident command.

However, as identified above the strongest example of the remotely supervised firefighter is represented by SCBA operations where it is known that in conditions of heat, limited vision, and cognitive challenge, they are also making choices. This is where the cognitive stress from knowing their judgement and decision making can result in personal injury, injure another member of the team or worse still, compromise victim safety can influence the ‘moment-of-choice’ of the firefighter and enable transition to person-as-cause (Young et al

2014). However, studies of judgement and decision making specifically focussed on the role of firefighter as opposed to their incident commanders are exceptional and much needed.

2.9 Literature Review Summary.

The effect of modernisation on the Fire and Rescue Service (FRS) has resulted in a significant reduction in reported injury to firefighters during emergency response operations. In the five-year period preceding the introduction of modernisation heralded by new legislation in 2004/5 there was an average of 2,974 reported injuries per year. Six fatalities also occurred in this period. By 2010 the annual report recorded 1,229 injuries and two fatalities, and at the commencement of this research in 2015 this was 1,1049 with one fatality. The most current data report records 963 injuries and no fatalities (Home Office 2021).

In recent years, albeit slightly, annual Home Office reports have started to record a downward trend in reported injury, the most recent publication (Home Office (October) 2021) associates this reduction with a corresponding reduction in the number of incidents being attended. Apart from this obtuse recognition that injury rates ‘may’ have a relationship with the frequency of exposure, these annual reports offer no understanding of factors influencing the ‘moment-of-choice’ of those involved. Despite which, many aspects of choice and error leading to injury causing accidents are known by FRSs.

Scientific and scholarly scrutiny of human factors that can influence erroneous actions has produced an extensive architecture of error. Fundamental understanding of error, cognitive performance and contextual factors that can influence judgements, choices and actions are now extensively scientifically labelled and explained. Unintended but identifiable erroneous actions are no longer labelled as ‘human error’, the literature instead represents them as ‘unsafe acts’. They are the start point for accident analysis and essential to understanding causation, the origin of which lies in upstream activities. Characterised as latent conditions these upstream organisational and systemic failings are thought by some to be inevitable.

However, contemporary thought now asks if the pendulum of interest in those upstream activities has swung too far away from scrutiny of those directly involved in unsafe acts. (Difford 2011; Filo, Jun, and Waterson, 2019; Reason, Hollnagel and Paries, 2006; Underwood and Waterson 2013). For the firefighter, the intention is to mitigate harm. In doing so, occasionally they will put themselves in harm's way to preserve the safety of others. The environment in which these tasks are sometimes performed is inherently unsafe. Such an intentional but unsafe act may not turn out as intended and may result in their own 'active' injury or the 'passive' injury of another. Yet the literature suggests there is no specific theory applicable to injury causation; injury and accident are treated as having a symbiotic relationship, one where accidents do not always result in injury, but injury is, all too often, the undesired outcome of an accident.

With attention directed away from the sharp end focus of the operator, now upstream interest lies in the way organisational controls and barriers designed to compensate for human failure can be weakened by managerial deficiencies. An important purpose of the defensive function of these barriers is to constrain the liberty of those at the sharp end. Deficiency in their design or the transition of operators to the mode of person-as-cause by crossing the defensive barriers created by them underpins how the human system component, whether intentional or unintentional, can create accident causing conditions. This also draws attention to the way system defences can be weakened by the fallible decisions of managers and compromised by operators influenced by the way they make sense of the context in which transition occurs and the intention that makes it necessary.

Sensemaking or making sense of the chaos of the unexpected and ambiguous context of the emergency response domain has been extensively researched and reported throughout the literature of the Naturalistic Decision Making (NDM) paradigm. The dominant focus of NDM lies in understanding the cognitive processes adopted by skilled decision makers, informed from memory of their previous experience(s). The application of this research to the emergency response domain of the FRS is notable.

However, the expression ‘firefighter’ is used generically throughout the paradigm to describe research participants. Closer scrutiny reveals that it is the role of supervisors and managers in their guise as incident commanders that dominates this research interest. There is little evidence of the same interest being applied to the specific role of firefighter but the view that judgements and decisions of a commander with 20 years of experience would be much more accurate than those of a ‘rookie firefighter’ prevails. Nevertheless, regardless of their level of experience, when dealing with fires and implementing the requirements of an incident commander’s tactical plan, it is more likely for unsupervised firefighters to be acting in response to their own judgement and decision making.

The risk appetite of incident commanders and the risk-taking behaviour of firefighters is directed by a firefighter’s safety maxim which balances risk and benefit or transitional behaviour. An additional and essential tool for exercising this balance and sustaining the mode of person-as-barrier in the rapidly changing environment of an incident is the decision-making process known as Dynamic Risk Assessment (DRA).

Relevant to the influence of experience, the number of fires attended in the last 10 years has reduced by almost 56%. This has raised concerns over the lack of opportunity for commanders to experience the challenges of incident command decision making in their ‘natural’ environment and resulted in a proliferation of experience through simulation. Consequently, the competent performance of incident commanders is now subject to many variants of scrutiny and reflective learning in the ‘fail safe’ environments of simulation. Rarely, if at all, is the tactical judgement and decision making of a firefighter working remotely under the most testing of physical and psychological conditions of their ‘natural’ environment subject to a similar level of ‘individual’ scrutiny.

Academic peer reviewed study of the decision-making behaviours and safe performance of firefighters is atypical. The most recent of which (Young 2012, Young et al 2014), being conducted by a researcher with several years experience as a WDS firefighter, supervisor and manager. Yet, this thesis argues that those in the role of firefighter are more likely to actively or passively experience the consequences of either their own or another’s unsafe acts.

Where scrutiny and reflective learning of ‘unsafe acts’ resulting in injury are concerned, national data reports are silent. Whilst they report the number of operational injuries, they do not indicate the activity being undertaken at the time, neither do they indicate if the injured party was involved actively in the unsafe act or a passive victim. More importantly, many relevant human factors that can influence outcomes at their ‘moment-of-choice’ are also not included. Yet, all FRSs maintain records where this important and relevant knowledge of factors impinging on unsafe acts resulting in injury can be found. The chapter that now follows explores the methodology used in the development of three studies designed to examine the human factors data readily available to FRSs which can better inform their understanding and provide answers to the research questions of this thesis. In meeting the primary aim of this research this understanding can not only reduce the likelihood that firefighters will suffer the consequences of their own or another’s unsafe acts, it will also contribute to error management and injury reduction in the FRS.

3. METHODOLOGY.

3.1 Introduction.

This research is concerned with the human factors (HF) that may contribute to firefighter injury and whether the Fire and Rescue Service (FRS) adequately acknowledges their influence when investigating, recording, analysing, or reporting accident causation. Of equal importance is the way knowledge of HF arising from such events is used by the FRS to influence learning and development and injury reduction. A mixed methods approach is adopted to explore these issues using both quantitative and qualitative methods to examine several factors that influence outcomes at the 'moment-of-choice' of firefighters that can result in injury. By focusing on firefighters as opposed to their incident commanders, not only does this research contribute to improved understanding of the critical decision making of firefighters, but it also offers the potential to reduce the likelihood that firefighters will suffer the consequences of their own or another's unsafe acts. The introduction chapter states the main aim and objectives of this research. This mixed methods research methodology sets out to address them by using three studies. Table 3.1 below demonstrates how they are addressed by the following methodology.

The first of three studies described in section 3.4 below uses quantitative methods to consider in greater depth the first research question: How effective is the FRS at gathering, analysing, and understanding the pre-conditions and human factors of accident causation. The question of frequency is expanded beyond a count of injury occurrences. For the first time in the analysis of firefighter injury, several variables that represent the preconditions of accident causation such as the demographic, temporal, environmental and contextual characteristics are captured. An 'error type' taxonomy that differentiates between decision errors, skill-based errors, perception errors and violations also establishes an additional variable for analysis.

Table 3.1 Comparison of research aim and objectives with methodological approach.

Aim and Objectives	Relevant Study	Research Question Addressed	
		Primary	Secondary
The main aim of this research is to improve error management and contribute to injury reduction in the Fire and Rescue Service.	Study 1 - Data Capture Study	RQ1 RQ2	RQ3
	Study 2 - Human Factors Analysis	RQ3	RQ1 RQ2
	Study 3 - Injured Party Experiences	RQ1 RQ2	RQ3
Identify the extent to which FRSs gather, analyse and understand data relating to the preconditions, unsafe acts and decision-making deficit of reported operational injury. In particular, the extent to which as critical decision makers, firefighters experience the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander.	Study 1 - Data Capture Study	RQ1 RQ2	RQ3
	Study 3 - Injured Party Experiences	RQ1 RQ2	RQ3
The second objective is to determine if a sector specific analysis tool can be developed and used to better understand the human factors of accident causation and inform targeted intervention strategies.	Study 2 - Human Factors Analysis	RQ3	RQ1 RQ2

The initial data capture study is followed by a HF analysis that uses quantitative measures to examine the coding judgements of the managers participating in the error typing judgements of the first study. This second study also examines the application of a HF analysis tool that could be developed into a domain specific taxonomy and applied to the accident causation analysis of the FRS.

A third study then uses mixed methods to analyse information provided by firefighters who have sustained injury whilst attending incidents. In response to RQ1 and RQ2 this analysis of injured party (IP) experiences seeks to add understanding to the preconditions influencing the 'moment-of-choice'. To commence, the following section explains the research framework and 'world view' influencing the chosen approach and the philosophical stance taken in seeking this improved understanding.

3.2 Research Framework.

Trafford & Lesham (2008) assert that the framework of the research approach lies in making epistemological and ontological assumptions explicit (Trafford & Lesham, 2008:97). The epistemology of the research framework that influences the deductive approach of the first two studies described below is first found in the literature review. This is where historical and contemporary literature considers aspects of existing theory and acquired knowledge of human error and accident causation. Quantitative analysis is then used as a deductive examination of the extent to which the FRS explores the influence of the preconditions of unsafe acts and unsafe acts themselves in the judgement and decision-making of firefighters. The contemporary view of judgement and decision making held by the Naturalistic Decision Making (NDM) paradigm is examined, where the context of Recognition Primed Decision (RPD) making and Situation Awareness (SA) and the theories on which they are based establishes the knowledge that this chapter uses to seek answers to RQ1 and RQ2. To further explore the epistemology of firefighter injury, analysis of the first study identifies the potential for application of a HF diagnostic tool which is further tested in the second study with quantitative methods for coder agreement and applicability for development as a domain specific framework.

In a similar way, the introduction to this thesis establishes the ontology of the framework where, predicated on the existence of organisations as complex socio-technical systems, an overview of the operational structures of the FRS is provided. Ontology is also complemented in the literature review where the context of FRS error management explores the approach taken by the FRS to develop judgement and decision-making skills of an Incident Commander (IC). This is the social and cultural context *"…into which new recruits have to be socialised"* (Bryman 2012:6). Here the thesis postulates on the existence of a disparity in the approach taken to develop similar decision-making skills in firefighters. This is an important factor identified in the literature review, one representing a gap in knowledge. The third study described below examines the social reality of the psychological precursors and mechanisms that influence the judgement and decision- making experiences of firefighters through analysis of interview responses.

Whilst this epistemological and ontological positioning represents the philosophical assumptions of the research approach, it does not represent a holistic paradigm. A research paradigm is defined as "*a worldview, together with various philosophical assumptions associated with that point of view"* (Teddlie & Tashakkori 2009:84). Arguably, with the locus of interest of this research being on human experience explored by mixed methods the philosophical positioning is one of pragmatism. Morgan (2014) also argues that the use of mixed methods in social research has stronger associations with pragmatism as a research philosophy which lies in the way research is treated *"as a human experience based on the beliefs and actions of the researcher"* (Morgan 2014:1051). This philosophy follows a cycle of inquiry where a researcher's influence is one of reflection, where choice of research originates in beliefs and reflection on the outcomes of actions that in turn have affected the researcher's beliefs. This cycle of inquiry and experience is demonstrated by the systematic five step approach depicted in Dewey's model of enquiry below (Morgan 2014), (Figure 3.1).

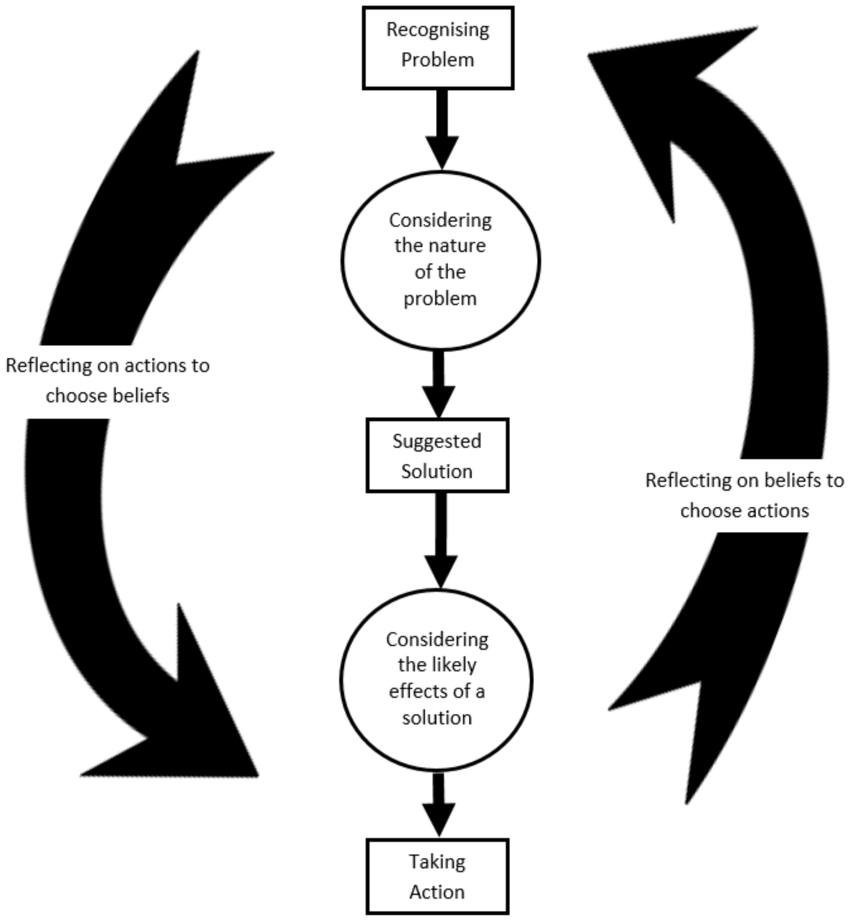


Figure 3.1. Dewey's Model of Enquiry. Adapted from Morgan (2014).

In this case the researcher has recognised and reflected on the problems, directly or indirectly influenced by factors affecting firefighter injury in the emergency response domain. Using three studies, the chosen pragmatic methodology then considers and evaluates how the adopted process of inquiry and reflexivity seeks to create new knowledge and improved understanding can lead to a possible solution.   This is where a mixed methods approach in gathering, and analysis of research evidence represents the action taken to seek an improved understanding of firefighter injury and evaluate the implications of the results. The process of evaluation that follows compels the need to once again reflect on factors affecting firefighter injury and in doing so, through chapters offering discussion and conclusion demonstrate modified beliefs, respond to the aims, objectives, and research questions of this thesis.

Arguing for the acceptance of the pragmatist philosophy Morgan (2014) asserts that focusing on the nature of human experience replaces the 'older emphasis' on ontology and epistemology (Morgan 2014:1048). In this thesis the nature of the research problem lies in the deficiency of any valid accident research or analysis of HF effecting the 'moment-of-choice' of firefighters. However, the chosen research approach can also be threatened by a researcher's influence on participant behaviours (Robson 2007), causing participant bias in the form of 'obstructiveness'. Researcher's biases can also influence their selection of participants for interview, the selection of questions they will ask, or their choice of data for analysis. However, the pragmatic philosophical positioning of the chosen methodology is not only complimentary to creative innovation and problem solving but also the reflexive influence of the research experience, and research outcomes (Joas, 1993). All of which can threaten the validity of the chosen research approach. Consequently, the methodology of this research uses three studies to minimise the consequence of premature conclusions that could be influenced by a single method or analytical approach.

In order to improve reliability and validity, triangulation is a method that can be employed to cross check the results of research using quantitative data against those using a qualitative strategy (Bryman 2012). Providing three sources of data to *"…gain further insights into reality on the ground"* (Grix 2001:141) as described above, the studies are used to triangulate the social reality of the FRSs knowledge and use of HF effecting the 'moment-of-choice' of firefighters. This approach serves to reduce any threat to validity from the influence of the researcher on the participation, behaviours and responses of participants and any inherent researcher biases. The triangulation model in Figure 3.2 below demonstrates how the three studies of this research set out to improve reliability and validity in the gathering and analysis of data.

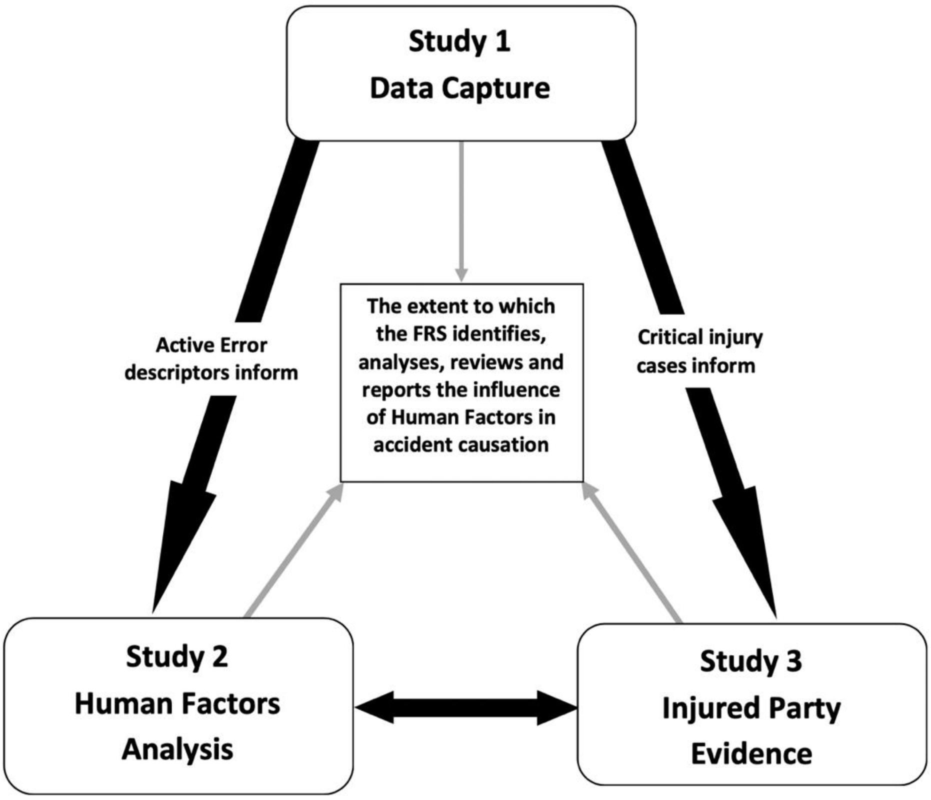


Figure 3.2. Triangulation Model demonstrating the relationship between research studies.

The following section of this chapter explains the context influencing the methods used to explore the 'moment-of-choice' of firefighters. The way emphasis on the term 'firefighter' is misplaced in the judgement and decision-making research of the fire sector is explained as are the constraints to researching firefighter injury in the 'natural' setting of fire service operations and their influence on the methods chosen in the development of a research approach based on three studies.

3.3 Context.

The research literature revealed extensive evidence of the term 'firefighter' being used to describe the person responsible for strategic judgements and tactical decisions in the emergency response domain. Use of the term 'firefighter' as a generic descriptor is a misleading misnomer established in research throughout the NDM paradigm (Calderwood, Crandall, and Baynes 1990; Klein, Calderwood and Clinton-Cirocco 2010). When identified by their role, participants are described as 'Fireground Commanders'. However, FRSs throughout the UK describe front-line operational staff by their designated role. Given that the locus of interest of this thesis is the 'firefighter' it is important to understand that the description firefighter is applied exclusively to those operational staff who, in the role of firefighter, are more often than not, required to enter unsafe conditions to undertake the tasks resulting from the tactical judgements and decisions of their Incident Commander (IC).

Unsafe conditions are defined as *"any environmental condition that may cause or contribute to an accident"* (Stranks 2007:106). The role of the firefighter is predicated on society's expectations that they will enter an environment of 'unsafe conditions' to achieve the goal of mitigation and return an unsafe system state to one of safety. This would suggest that as a component of the FRS emergency response system, when acting on or attempting to control a system in an unsafe condition the firefighter is at the convergence of two systems, that which is now in an unsafe system state and the FRS system of mitigation.

This is the environment where outcomes arising from the action taken by firefighters following a critical decision-making episode may result in injury. An environment typical of the 'natural setting' examined by researchers of the NDM paradigm where circumstances are characterised as unexpected, inconsistent, and random. Where, without direct supervision, a firefighter can make an independent judgement, decision, and choice, one that may result in an injury causing accident. Such an erroneous or unintended outcome represents the deficit of balancing risk and benefit (Zhang, Polet, and Vanderhaegan 2002; Polet, Vanderhaegan, and Wieringa, 2002).

If such action results from a heuristic process that balances risk of injury with the benefit of outcome, it is arguable that the likelihood and possibly even the nature of injury has also been considered, and should it occur, not be entirely unexpected. The FRS describes this heuristic process as Dynamic Risk Assessment (DRA). It too is written with an inflection towards the role of the IC. However, the process of considering the presence of hazards, assessing the risk of harm that they present, and determining an optimum course of action to realise the benefit of choice suggests a more deliberative process is taking place. The NDM paradigm ascribes the more complex deliberative processes of Recognition Primed Decision (RPD) making and Situational Awareness (SA) to influencing the judgements, decisions, and action choices of ICs. Demonstration of knowledge, skill and understanding in these deliberative cognitive processes is also a requirement of the competent IC but not so the competent firefighter.

Further constraints influencing the chosen research approach lie in the environment in which injury causing deficit is realised. It is argued that *“human behaviour is always influenced by the environment in which it takes place”* (Leveson 2008:10). Leveson posits that it is in changing the environment in which behaviour occurs that has a greater long-term effect on human error, and that *“all human decision making is based on a person’s mental model of the system being controlled”* (Leveson 2008:13). Leveson further argues that to understand behaviour both the mental model of the firefighter and the operating environment must be examined (Leveson 2008:13). Yet, it is in the role of mitigator and interventionist that the firefighter finds her/himself in the critical, high-risk decision-making environment of unsafe conditions with change in system state as the goal.

The most valuable methodological approach to making such an ‘environmental’ examination is direct observation but the unsafe conditions of the incident environment present practical and theoretical challenges for the research observer (Branlat et al 2009). This is an environment where observers are not only likely to impede operations but also be at risk from them (Crandall, Klein & Hoffman 2006). This makes errors hard to detect and explain yet accounting for errors is amongst the most significant challenge of NDM research (Klein 1997; Lipshitz 1997).

Branlat et al (2009) considered the use of ‘body worn’ video cameras used by research participants to be a powerful alternative approach to capturing and gathering data. Contemporary NDM research conducted by Cohen-Hatton, Butler, and Honey (2015), involved two senior fire officers in an English FRS. Trained and competent to operate in the emergency response domain of the firefighter, both were able to enter the environment of unsafe conditions to conduct their research. They used participant ‘body worn’ cameras as a research tool to good effect in their investigation of operational decision making by Incident Commanders in simulated environments. In these circumstances situational cues could be controlled, mental models influenced, and post-performance reflection was, in-turn cued by video recall.

Video capture enables research scrutiny and collection of quantitative data (Branlat et al 2009). Crandall, Klein & Hoffman (2006) argue that there are circumstances where recording *“can result in misleading and cognitively shallow accounts”* (Crandall, Klein and Hoffman 2006:15). In the case of seeking evidence of deficit in the judgments, decisions, and choices of firefighters, whilst body worn video may capture voice recording, due to the often visually restricted environment caused by the presence of heat and smoke, in many cases video recording is not fully capable of revealing the visual context. Neither can it record the cognitive influences that impact the ‘moment-of-choice’ of the firefighter which represent an important focus of interest of this research. Therefore, in most circumstances, for an outside or non-competent observer, observation is simply not feasible in the incident environment (Branlat et al 2009).

To find out how research participants assess and make sense of events and make choices in an environment of unsafe conditions which non-competent observers are unable to enter Crandall, Klein & Hoffman (2006) advocate the use of other forms of data collection such as interviews, and Branlat et al (2009), the use of various forms of retrospective reports, such as case studies and guided interviews about unnatural incidents and critical incident techniques. These are the techniques used in the research methods described in the following section.

However, it is important to acknowledge the unique nature of the practitioner/researcher to the context of the research. Describing personal reflection, reflexive influences and pragmatic philosophy of the chosen methodology are not without their academic challenges. Conceptualising and constructing the three studies described below draws on 42 years' experience in the roles of firefighter, supervisor, commander, researcher and strategist in one of the UKs most prominent FRSs. It is in the latter years of this service that narrative explaining cause and effect of serious accidents and injury created the proclivity to pay closer attention to context, circumstances and characteristics and their influence on unintended outcomes. Unavoidable in this pursuit is the influence of the 'Human Factor'.

3.4 Research Design and Methods.

Three separate studies are used to examine the extent to which FRSs identify, analyse, review, and report the influence of human factors (HF) in accident causation. The first is a preliminary exploratory data capture and analysis exercise that obtains descriptive data from a representative sample of English FRSs, data not only critical to current FRS analysis, and understanding of the pre-conditions and human factors of accident causation, but also understanding of the active error more likely to result in injury when making a critical decision (RQ1 and RQ2). Within this data three important variables are used to inform the subsequent studies. An Active Error descriptor (AED) provides a variable that requires a classification of unsafe act influenced by Reason's summary of the psychological varieties of unsafe acts (Reason 1990:207), which distinguishes between errors and violations *"…committed in the presence of a potential hazard"* (Reason, 1990:206). The AED is used as a predictor variable to explore a broad range of data such as the demographic; temporal; environmental and contextual characteristics present at the time of an injury causing accident. Gathering this active error data also introduces participants to the first level of the error classifications of the HF analysis tool used in the second study. Also influenced by Reason's taxonomy the HF analysis tool described below is designed to examine the reliability of their judgements and the suitability of the chosen HF analysis tool for application to the emergency response domain of the FRS.

To identify suitable cases for the third study an Injury Activity variable identifies those cases where injury has resulted from the realisation of the deficit outcome of a critical activity. Critical activity is defined in this study as *"circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome".* The critical activity factor and the injury severity measure identifies a population of IPs that have experienced the deficit outcomes of a 'moment-of-choice' and a cohort of interview participants for the third study.

3.4.1 Study 1 – Data Capture.

The data capture study provides the opportunity to conduct an exploratory data analysis designed to achieve three objectives. Firstly, it identifies several demographic characteristics of personnel reporting 'operational injuries' in the emergency response domain of the participating FRSs. The second objective is to explore several variables that could inform aspects of the incident context of the preconditions of accident causation that may influence injury causing accidents. The third objective introduces the 'error typing' data set to the managers responsible for either the investigation and reporting of accidents or administration of the processes. In this way the data capture study reveals the extent to which HF are being considered by the participating FRSs in the process of gathering data for the analysis of causation. In doing so, Study 1 largely provides research evidence in response to RQ1 and RQ2.

Method -

Here, the reflexive and pragmatic challenge lies in the knowledge that most, if not all English FRSs hold data that could better inform understanding of the influence of HFs and that Fire and Rescue Authorities hold their Chief Fire Officers to account for the delivery of a Fire and Rescue Service (FRS). But as the accountable person and gatekeeper, the Chief Fire Officer (CFO) of every English FRSs was contacted.

In the early stages of conceiving this approach the framing effect of the research title was considered reflexively. The proposed title described 'research into factors influencing the extent to which firefighters contribute to their own operational injuries and/or those of their colleagues' and would appear on all correspondence. The realisation was that reference to 'contribution' suggests a degree of culpability in the actions of those causing injury, culpability itself being phraseology of the lexicon of blame and framing a request for participation in this way could discourage participation.

Consequently, the working title that appears on correspondence captures early reflexive experience in now referring to a 'Human Factors analysis of Firefighter injury sustained during emergency response operations: Implications for error management and injury reduction in English Fire and Rescue Services' and better reflects the pragmatic methodological approach. The framing effect of this new title not only alludes to what may be a gap in knowledge that lies in 'Human Factors Analysis', but also a research outcome based on the potential to improve 'error management' and reduce firefighter injuries.

The revised initial contact letter set out to explain the aim of the study, the data that would be sought and how the data would be used. Cognisant of the additional work demand falling upon those managers delegated to provide and manage the data returns, great emphasis was placed on acknowledging that the data sought would include some variables that may not normally be recorded during the process of injury investigation. In those circumstances where an FRS indicated difficulty due to staff resources, reflexivity and practical knowledge encouraged the offer of assistance with data gathering.

FRSs are required to report injury data annually to the Government Department responsible for Fire Service matters. The reporting period under scrutiny captures injuries sustained during routine activities, training for operations, and during emergency response operations in the 12-month period 1st April 2015 – 31st March 2016. Considering the additional workload for the managers involved, using this as the data capture period would enable participating FRSs to record any additional data for the study incrementally throughout the year rather than retrospectively when the reporting year had concluded. This approach would also enable managers to gradually acquire some understanding of Reason's taxonomy of 'error types' (Reason 1990) and their relationship with Rasmussen's cognitive performance levels (Rasmussen 1983) when making the active error judgements required by the error typing variables.

The initial response of FRSs was limited with only nine agreeing to participate. A follow-up contact to non-responding FRSs was made six weeks after the initial mailing date. This resulted in an additional 12 positive responses. In each case a meeting was offered to explain in detail the aims and objectives of the research and seek solutions to the additional data gathering challenges. By August 2015, 31 of 46 English FRSs had agreed to participate in the data capture study. However, due to the impact of the autumn FRA budget estimates and subsequent organisational restructure plans, this number was later reduced to 26, as several participating FRSs concentrated their diminishing resources on service delivery. The final analysis was conducted on data provided by 18 FRSs.

In compiling their annual data returns FRSs are still gathering data and concluding accident investigations for several months after 31st March. This influenced the data gathering conclusion of the study (30th June 2016). This also coincides with the final date for FRS submission of data returns to the Home Office. By this date, returns had been received from 9 FRSs. Several additional FRSs had requested more time which resulted in the need to extend the period of ethical approval to include the remainder of 2016. However, influenced by the number of late responses from FRSs the period of ethical approval was extended until 30th June 2017. At the conclusion of the first study, 417 cases had been provided which represented 40% of injury cases reported to the Home Office by FRSs for the period 2015/16.

To explore some of the HF variables of accident causation five data sets not normally published in annual government department reports but available to all FRSs were gathered and established and subject to descriptive data analysis: demographic, temporal, environmental and contextual variables (see Chapter 4 below). In addition, Reason's classification of unsafe acts (Reason 1990) and Rasmussen's cognitive performance levels (Rasmussen 1983) were used to create the AEDs that establish a causal variable.

The primary area of interest of the study seeks answers to RQ1 and RQ2 and focuses on the association of HFs influencing the 'moment-of-choice'. Consequently, injury data is examined in five ways. Demographic variables capturing age and length of service at the time of injury are examined to determine the influence of what is described as acquired experience. Injury severity variables are explored for any significant relationship between severity and error type. Temporal variables relating to the time of injury and pattern of work are used to determine if an element of fatigue may have had any influence. Finally, context variables are examined to determine if there is any significant relationship between activity and active error.

Whilst this comparison enables focus on decision deficit (Polet, Vanderhaegan, & Wieringa, 2002), closer examination of factors affecting judgements, decisions, and choices at the 'moment-of-choice' of the Injured Party (IP) that lead to decision deficit are the focus of Study 3 (Chapter 6).

3.4.2 Study 2 – Human Factors Analysis.

The reflexive challenge in this study lay in the subjective belief that a sector specific accident analysis model used by managers responsible for the routine administration and in some cases investigation of injury causing accidents would be more acceptable to FRSs. The challenge was reconciled by the framing effect and emergence of 'error typing' based on the Active Error Descriptors (AEDs) of the first study, which captured the importance and compatibility of this second study. The data capture process of the first study introduces the concept of 'error typing' to the participating FRS managers responsible for the investigation, reporting and administration of accidents. To explore the reliability that could be placed on their choice of AED, this second study has two objectives. First, to examine the reliability that could be placed in the selection of various categories used to explore the HF that may contribute to firefighter injury when using a specific HF analysis tool. Second, and in response to RQ3, to examine the applicability of the chosen HF analysis tool to the emergency response domain of the FRS when modified to a more sector specific variant.

Choice of HF Analysis Tool -

The choice of HF analysis tool used in this study lies in the original work of Rasmussen (1983) that identifies the most common error type associated with a cognitive performance classification where mistakes and violations are recognised as being either knowledge or rule based, and lapses skill based. Recognising the influence of pre-conditions and their relationship with psychological factors Reason (1990) introduced the 'intention' of the operator committing an unsafe act to the context of accident causation and capturing Rasmussen's cognitive performance taxonomy created a ‘classification of unsafe acts’ (Rasmussen 1983, Reason 1990), (see figure 4.1, page 102).

Reason (1990) also argued that the origin of accident causing conditions can lie dormant in the structure or management of an organisation system. Over time these ‘latent conditions’ weaken the in-built system defences and allow a ‘trajectory’ of accident causing conditions to merge with the psychological pre-cursors that enable or influence the unsafe acts of operators. Described as the Swiss Cheese Model (SCM), this process was metaphorically modelled with barriers represented as four slices of Emmental cheese with holes allowing the ‘trajectory’. The first slice depicts the layer of organisational influence, the second the influence of supervision and management, and the third represents the pre-conditions that enable unsafe acts to occur. Finally, representing ‘Active Failures’ the fourth cheese slice captures unsafe acts themselves. This approach established the ability to focus attention on latent conditions present in a system as well as human error at the sharp end and became the scientific and academic foundation of the Human Factors Analysis and Classification System (HFACS) framework (Weigmann and Shappell 2003), (Figure 5.1, page 153).

HFACS was originally developed in response to a call for reduction in US Military Aviation accidents. Recognising how the limitation of the SCM lay in its failure to *“identify the exact nature of the holes in the cheese”* (Weigmann and Shappell 2003:49), Weigmann and Shappell produced a framework to be used as an accident investigation and analysis tool. Bridging the gap between theory and practice; HFACS identified and classified the human causes of aviation accidents; and was designed to *“define the latent and active failures implicated by the SCM”* (Weigmann and Shappell 2003). Since then, HFACS has been shown to be a comprehensive tool with diagnostic qualities that make it reliable, usable and whilst valid in both Military and

Civil Aviation, applicable to several other domains (Diller et al 2014), (Table 3.1 below).

HFACS is found to capture the entire range of system errors from those of the operator through to higher levels of management and governance in an efficient, hierarchical structure that reduces cognitive demand on its users (Beaubien & Baker, 2002). The data it provides can inform objective data-driven intervention strategies and track their level of success in achieving accident reduction revealing relative changes in incident and accident data. Its reliability and content validity have been repeatedly tested and demonstrated and its user-friendly categorisation scheme has consistently demonstrated acceptable to high levels of inter-rater reliability (Shappell & Weigmann, 2000; Salmon, Cornelissen & Trotter, 2012).

Consequently, the choice to use HFACS as the research instrument for this study lies in its academic utility as an established framework across many domains. HFACS is also compatible with the guidance provided to those SMEs, who possibly for the first time, made the active error judgements of the first study. This study also creates an opportunity to develop and test domain specific performance nanocodes for the application of HFACS to the emergency response context of the FRS.

Method -

Following initial scrutiny of data provided for the first study an email response requesting missing data or reconciliation of 'local' phraseology was sent to the participating managers. This email included an overview of the second study and its link with the error typing data set of the first study. Several had not only actively engaged with the research but had responded meticulously to the requirements to identify the AEDs of the first study (n12). At this stage, expressions of interest for participation in the second study were invited from this small group seven of whom agreed to participate in this second study.

The managers participating in Study 2 were familiar with the investigation, reporting and administration of injury causing accidents in their respective FRSs. All have managerial responsibility for Health and Safety. Four of the participating managers have experience of investigating injuries at the fourth and fifth level of the continuum of consequences (Figure 4.2 page 114).

One of the participants also had experience of investigating and reporting an event involving two firefighter fatalities. All had been trained in accident investigation prior to this study and considered to be subject matter experts (SMEs).

Their participation in Study 1 established familiarity with the selection of a category of active error descriptors (AEDs) used to describe skill, decision and perception based errors as well as routine and exceptional violations. It is these that also represent the unsafe acts of the first failure level of HFACS. It could be argued that the entire focus of data provided in Study 1 was unsafe acts. However, at the second failure level of the HFACS, the environmental group of the preconditions of unsafe acts explored in Study 1 are represented in the physical environment causal sub-category. Although, some categories relating to the conditions of individuals could further be interpreted to align with discussion on the association between fatigue and the decision errors of unsafe acts. In each case, all aspects of the HFACS failure levels of unsafe supervision and organisational influence were being experienced by participants for the first time.

Table 3.2 Examples of peer reviewed research involving the application of HFACS in domains other than Aviation.

Authors	Domain	Publication Title	Year
Ryerson, M, Whitlock, C.	Wildland Firefighting	Use of Human Factors Analysis for Wildland Fire Accident Investigations	2005
Celik, M, Er I D	Shipping	Identifying the Potential Roles of Design-based Failures on Human Errors in Shipboard Operations	2007
Paletz, S B F, Bearman, C, Orasanu, J, Holbrook, J	Social/ Psychological	Socializing the Human Factors Analysis and Classification System: Incorporating Social Psychological Phenomena Into a Human Factors Error Classification System	2009
Patterson J M, Shappell S A	Mining	Operator error and system deficiencies: Analysis of 508 mining incidents and accidents from Queensland, Australia using HFACS	2010
Diller, T, Helmrich, G, Dunning, S, Cox, S, Buchanan, A, Shappell, S.	Health Care	The Human Factors Analysis Classification System (HFACS) Applied to Health Care	2013
Hughes, A M, Sonesh, S, Zajac, S, Salas, E.	Emergency Medical	Leveraging HFACS to understand medication error in Emergency Medical Services (EMS): A systematic review.	2013
Madigan, R. Golightly, D. Madders, R.	UK Rail Safety	Application of Human factors Analysis and Classification System (HFACS) to UK rail safety of the line incidents	2016
Theophilus, S C. Esenowo, V N. Arewa, A O. Ifelebuegu, A O. Nnadi, E O. Mbanaso, F U.	Oil and Gas Industry	Human factors analysis and classification system for the oil and gas industry (HFACS-OGI)	2017

Once gatekeeper approval was confirmed a ‘guidance pack’ was provided to participants which included written guidance on the application of HFACS (Appendix

1). Prior to releasing the guidance pack an acceptance test of its usability was conducted using two of the original SME cohort who were not participating in the analysis stage of the second study. This beta testing was specifically designed to consider the usability of the guidance pack that participants of the second study would receive.

The guidance pack consisted of a 16-page document (Appendix 1), that explained the contribution the second study could make to improved understanding and the potential for a reduction in firefighter injury. Firstly, reiterating the metaphor of the SCM, the guidance explained it's link to the HF analysis tool being used in Study 2 described below. The guidance then described the analysis tool itself and established its link with the AEDs of the first study. The final section of the guidance document explained how the accompanying case study and workbook should be used and included a step-by-step guide to conducting the analysis.

Beta testing largely resulted in amendments to overcome inconsistency in the written style which it was felt changed frequently between formal academic language and a more informal user-friendly instructional style. Although not invited from the two participants, several observations were made about category identification, the causal categories being used and their domain specific interpretation. The process of moderation that addressed these concerns is separately reported in section 5.2 below. The timing of this study was influenced by work demands of the participants and commenced in February 2017.

The participants (coders) were given three months to conclude their analysis of the first Case Study (CS1) which was based on two reports published following investigations into the deaths of three Firefighters and a Watch Manager at a warehouse fire in Atherstone-on-Stour, Warwickshire in 2007 (Fire Brigades Union

2014, Warwickshire FRS 2016). These two reports comprised of 111 pages which were subsequently condensed into a single case study document of 38 pages that consisted of an abridged narrative of events; sequential timed events plot; and a summary of recommendations (Appendix 3). On completion, reliability testing and analysis of categorisation and coder consistency was conducted using the Krippendorff Alpha (Kα) diagnostic measure and also comparison of percentage agreement (see Chapter 5 below). This also served as an early indication of the suitability and applicability of the original HFACS taxonomy to a more sector specific variant applicable to the FRS domain was explored (Chapter 5 below). Revised guidance based on interpretation of nanocode statements and comments of participants following CS1 was then provided with the second Case Study (CS2).

CS2 was similarly based on reports published following investigations into the death of a Firefighter at a fire in an Edinburgh Bar in 2009 (Fire Brigades Union 2017, Scottish FRS 2016). Comprising of 155 pages they contained significant narrative detail. However, participant comments following CS1 indicated difficulty in determining suitable responses for the higher level HFACS category - Organisational Influences. It was consequently decided to exclude this category from CS2. Excluding detail relating to organisational influences enabled the relevant background and sequential timed events plot to be condensed into a single document of 16 pages (Appendix 5). Participants were given a further three months to complete and return their CS2 analysis, their involvement concluding by 31st August 2017.

3.4.3 Study 3 – Injured Party Experiences.

The methods to be applied in this study are influenced by the Critical Decision Method (CDM) of the original research on Fireground Commanders conducted by Klein, Calderwood & Clinton-Cirocco (2010). Their semi-structured interview and a quasi-naturalistic approach is used to probe the decision making of participants who have experienced the deficit outcomes of a ‘moment-of-choice’. The study of injured party (IP) experiences sets out to achieve two objectives. Firstly, from an IPs own recollection of the decision-making episode that resulted in injury, the reliability and validity of aspects of the data gathered in Study 1 can be triangulated (Figure 3.2 above). The main focus being to compare the critical nature of the activity at the time of injury and the active error judgements applied by the subject matter experts in the data capture exercise of the first study. This informs the second objective which is to explore the environmental and contextual characteristics and HFs that influenced judgements, decisions, and actions at the ‘moment-of-choice’ and the utility of the chosen action that resulted in the deficit outcome. In turn these study objectives contribute to addressing RQ1 and RQ2 above (see page 13).

Method -

Here the reflexive challenge lay in seeking an injured parties (IPs) own account of the preconditions and context influencing the unintended outcomes of their ‘moment-of-choice’. From experience it was known that their anonymous and confidential participation would be influenced by the hierarchical workplace structures, and test trust relationships in both the cultural and social communities of firefighters and their supervisors and managers. Manifest as what is described as ‘risk aversion’, this proved to be the case and had a significant influence on the research approach as explained in the discussion of Chapter 7. The planned approach for obtaining injured party experiences is based on the retrospective interview of the Critical Decision Method (CDM) originally developed by Klein, Calderwood and McGregor, (1989). The cognitive probing of the CDM allows focus on the knowledge, skills, understanding and experience (components of competence) applied by IPs in a critical decision-making episode.

An additional reflexive challenge lay in acknowledging the ethical challenges of interviewing IP’s who may have encountered an extremely traumatic experience.

Whilst anonymity, confidentiality and informed consent have great importance, two of the most significant challenges lay in the 'sensitive' nature of the interviews and the potential that the events under scrutiny may later be subject to litigation. Elmir et al (2011) define a sensitive topic as *"having the potential to cause physical, emotional or psychological distress to participants or the researcher"* (Elmir et al 2011:12). The strategy for dealing with this potential is therefore an important aspect of the proposed approach and starts with the process of selecting participants.

Selection of Interview Participants -

The intention of this third study was to interview a sample of IP's who had realised the injury deficit of a critical decision-making episode. Of the 417 cases reported by FRSs participating in Study 1, *n*93 met this criterion. Data returns for Study 1 also identified injury severity based on time loss from work. Descriptive data analysis identified *n*64 no time loss injuries, *n*8 where the IP was absent from work for up to 7 days, and indicating a more severe injury, *n*21 in excess of 7 days.

A letter seeking a meeting to explain the objectives of the study was sent to the relevant CFOs to establish gatekeeper approval and permission to contact their IPs with view to seeking their individual participation. In recognition of the challenges of such a process, these meetings would serve to emphasise the anonymous nature of their IPs participation and the confidential nature of their interview responses. More importantly, that all/any information obtained would not be disclosed to the employing FRS. It was also intended that these meetings would establish the best means of contacting the as yet anonymous IPs to inform them of the research project and seek their participation.

Reflexive experience resulted in anticipation that natural random selection of participants would occur in several ways. Firstly, the unpredictable nature of sustaining injury whilst undertaking a 'critical' activity established a random long list.

The unknown willingness of gatekeepers to permit contact with their employees would then 'select-out' several potential participants. As a subordinate gatekeeper, the nominated managers may not prioritise the need to locate and contact potential participants. Additionally, several potential participants would be excluded if pursuing litigation and finally, the random nature of IP agreement to participate and trust in confidentiality would also have an influence on participation.

13 FRSs agreed to participate in Study 3 which reduced the number of participants of the original anticipated cohort to *n*49 to which the random selection characteristics would still apply. In anticipation of positive responses, and to manage the resulting interview schedule, participant contact letters were divided into two groups. The first group of *n*26 were sent to the relevant FRS managers for identifying and forwarding to IP contact locations/addresses. To establish confidence in the confidential and anonymous nature of participation none of the contents of the participant information and consent letters were known to the managers involved. In addition, each letter was uniquely tamper-proof sealed with a label displaying the participant case number the content and purpose of which was explained in the enclosed letter. Subsequently, only one IP made contact to arrange an interview. Forwarding the remaining 23 contact letters had the same result.

Given that some of the questions about personal injury were 'sensitive' in nature and the potential existed for them to *"generate emotional responses"* (Barnard, Gerber, and McOsker 2001:33). To reduce the likelihood of vulnerability participants were given a choice of time and venue for interviews where they felt they would be comfortably able to participate (Elmir et al 2011). Elmir et al found that a private environment was important to participants where 'do not disturb' arrangements are advantageous (Elmir et al 2011:14). In anticipation of managing a demanding interview schedule, these arrangements were made immediately upon receiving a positive response. In each case, the two responding participants agreed to meet at their local fire station. However, no further IP interest in participation was received.

By June 2017, with only 2 responses, the plan to interview IPs identified in the first study was suspended. To avoid the loss of evidence of IPs own accounts and their important contribution to the study, this challenge was met by adopting an alternate approach that allowed completely anonymous participation using an online questionnaire survey. In doing so, it was accepted that it would no longer capture the injury cases explored in Study 1.

Constructed on the Bristol Online Survey (BOS) platform the questionnaire comprised of 40 questions under eight pre-designed themes (Appendix 4) which were designed to elicit data relating to the first two HFACS categories of Unsafe Acts and Preconditions of Unsafe Acts at the 'moment-of-choice'. In keeping with the original intention of the study, the majority of questions replicated those of the CDM. The design and application of the questionnaire, approach to thematic analysis and results are discussed in Chapter 6 below.

3.5 Summary.

In summary, exploring the HF effecting the 'moment-of-choice' of firefighters when they make a judgement, decision, and choice independently of their Incident Commander has several philosophical, practical, and ethical constraints. Using mixed methods, the three studies described above consider the challenges this presents when exploring the influence of psychological preconditions and unsafe acts for error in judgement and decision making and a means by which they can be identified. The following three chapters describe additional methodical structure and provide the analysis and results of the methods used in each study for seeking an answer to the three research questions of this thesis (see page 13).

4. STUDY 1 - DATA CAPTURE (RQ1, RQ).

4.1 Introduction.

The accident and injury data arising from emergency response operations now published annually by the Home Office (2021) offers limited value when seeking to understand the preconditions and unsafe acts that lead to injury. However, FRSs maintain an abundance of data such as the demographic characteristics of those involved, as well as the temporal, environmental and contextual characteristics that represent the preconditions of accident causation. These variables identify data that could better inform analysis of accident causation and FRS intervention strategies. This first study uses a sample of this data provided by 18 FRSs that represents ≥40% of all reported injury events occurring in the emergency response domain in the year of the study 1st April 2015 - 31st March 2016, as such, it is a sample on which results can be generalised.

4.2 Study 1 Analysis.

Descriptive data analysis was first undertaken to describe and summarise generic parameters of five data sets representing the injury profile and the demographic, temporal, environmental and contextual characteristics of the reported injury cases. For ease of description and grouped under separate generic headings descriptive values are first presented in table format under each section heading. Associated analyses of each data set are based on exploratory statistical analyses and provide tentative evidence of relevant interactions between what are described as ‘active error descriptors’ and several selected relevant factors within each data set. Additional narrative context is included with each section to assist both understanding and interpretation.

4.3 Human Factors - Active Error.

In response to research questions RQ1 and RQ2, this first study sets out to examine several factors that influence the decision making, actions and behaviours of firefighters which contribute to the accident-causing conditions that result in injury to themselves or other firefighters.

Reason (1990) argued that accident-causing conditions originate in the structure or management of an organisation system and described them as 'latent conditions'. Over time they weaken the defensive barriers of a system and allow a 'trajectory' of accident-causing conditions. In the FRS these barriers are represented by artifacts such as legislation and guidance; the provision of appliances, equipment, and risk information; and the acquisition of knowledge and skill through training and experience(s). Weakness in any of these can merge with situational factors and a combination of human factors (HFs) described as psychological pre-cursors that enable or influence unsafe acts (Reason 1990). For the firefighter, the operational environment where this occurs is inherently unsafe, this is also where, regardless of intention, an unsafe act may result in their own 'active' injury or the 'passive' injury of another.

This research focuses on these psychological pre-cursors or HFs that in some way enable or influence the unsafe acts of firefighters and contribute to their injury. The approach taken is to explore several situational factors that represent the immediate preconditions of accident causation that can influence judgements, decisions, and actions at the 'moment-of-choice'. Here, HF are represented by the concept of 'error typing' where an Active Error Descriptor (AED) is used to identify if an unexpected outcome at the 'moment-of-choice' resulted from a decision-based; skill-based; or perception-based error; or violation.

Recognising the relationship between psychological and situational factors, Reason introduced the 'intention' of the operator committing an unsafe act to the context of accident causation and based on the skills, rules and knowledge taxonomy of Rasmussen (1983), created a 'classification of unsafe acts' (Figure 4.1 below). Rasmussen identified the most common error type associated with cognitive performance and identified mistakes and violations as being either knowledge or rule based, and lapses skill based (Rasmussen 1983). Both knowledge and skill have been identified as important components of competence. The AEDs used as an independent variable in this analysis are derived from Reason's classification of unsafe acts (Reason 1990).

The AED taxonomy of this study simplifies the original classification of unsafe acts. Decision errors capture both the rule based and knowledge-based mistakes of intended action. The attentional and memory failures of unintended action are categorised as skill-based errors. The perception category represents the influence of environmental factors that can influence sensemaking leading to a false impression of reality. Finally, in keeping with the original classification of unsafe acts, both routine and exceptional violations also represent intended actions (Table 4.1 below).

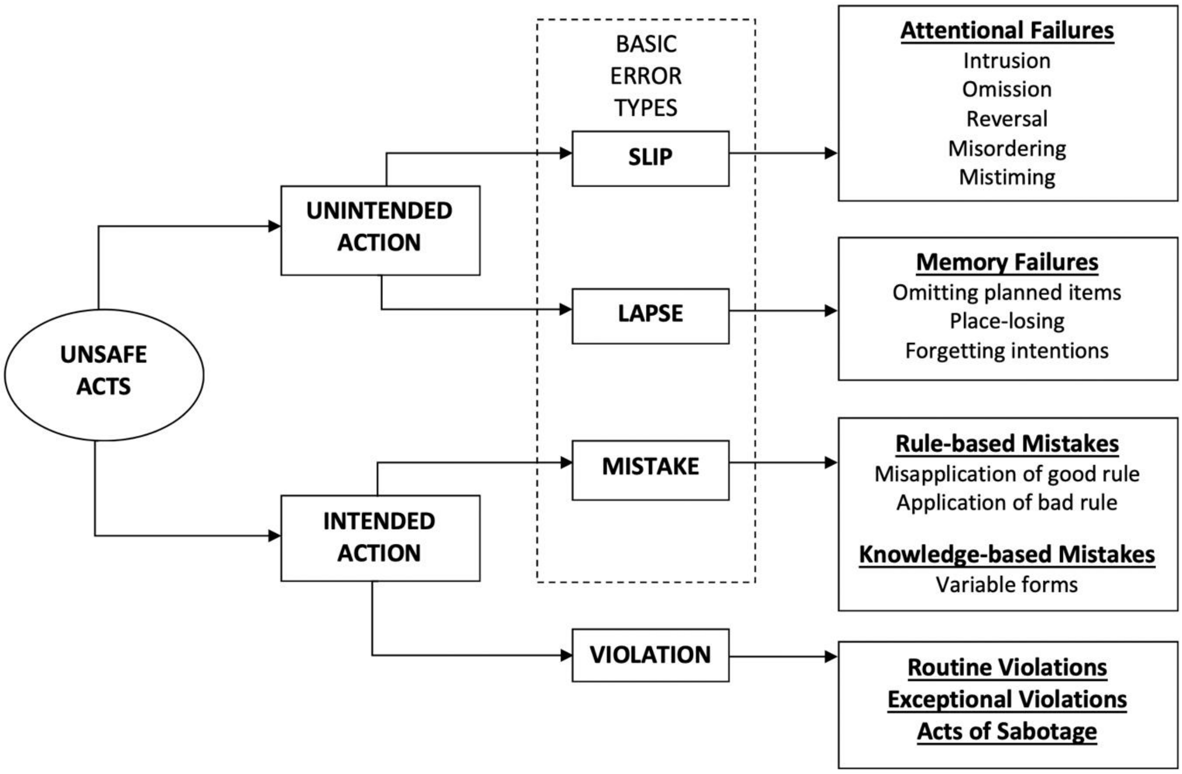


Figure 4.1 Reason's Classification of Unsafe Acts. Classified by intention and distinguishing errors from violations. Adapted from Reason (1990:207).

Using AEDs in this way to determine the decision error type of an unsafe act that leads to injury, the data capture study makes an original and important contribution to research not only on firefighter safety in the emergency response domain but safety in all workplaces. It also holds the potential to inform the development of targeted injury reduction strategies for the FRS. For the FRS, these findings are significant to the debate about the extent to which the influence of decision errors and their influence at the ‘moment-of-choice’ should be given when investigating, recording, analysing, or reporting accident causation, and when training firefighters.

The start point for the analysis of this study is to establish the results of the descriptive data analysis of the Active Error Descriptors (AEDs) used as an independent variable to explore the significance of any relevant interactions between the selected injury profile; demographic; temporal; environmental and contextual factors explored in this study. Table 4.1 above provides a brief narrative description of each error type and the frequency with which it was identified as a pre-cursor to an injury causing outcome in the data capture study. In 56 cases, the data was not provided, the descriptive analysis is based on evidence provided for 361 cases.

Of particular importance, based on the judgements of the managers participating in the data capture exercise described in the methodology of Chapter 3 above, the larger proportion of injury cases in the study (37.4 per cent, *n*135), involved a skill-based error. Injury resulting from decision errors are equally as prominent (31.3 per cent, *n*113). They are represented by those unsafe acts that result from rule and knowledge-based mistakes. Skill and knowledge are fundamental components of competence. To perform competently in the emergency response domain there is an expectation that both firefighters and their commanders establish and maintain the skill, knowledge and understanding to perform their duties effectively.

Table 4.1 Descriptive analysis of Error Types used as Average Error Descriptors.

Error Type	Count	Valid %
Decision Error Often referred to as honest mistakes decision errors represent intentional behaviour that proceeds as planned but the plan itself is inadequate or inappropriate for the situation. They can involve a poor choice when presented with an option. Or they can occur when the situation is not well understood and formal response options are not available, where the invention of a novel solution is required.	113	31.3
Skill Based Error Skill based behaviour occurs without conscious thought. It develops with knowledge of the practical application of taught and learned skills. Skill based action can be particularly vulnerable to failures of attention and/or memory. They are the simple attention failures of highly automatized behaviour. A typical example would be missing a turn at a familiar road junction or missing an appliance cab step when stepping up or down.	135	37.4
Perception Error This is about not making sense of the situation, having a perception that differs from reality because of the environment. Not understanding direction when vision is impaired, or where size, shape and dimensions are misjudged in conditions of poor visibility.	68	18.8
Routine Violation These tend to be habitual and, in some way, tolerated by 'blind eye' supervisors or managers. Such as allowing routine violation of driving in excess of the speed limit during non-emergency driving. Simply seen as 'bending the rules' they are allowed by the line of supervision or management which is where their 'permissive' origins may lie.	17	4.7
Exceptional Violation These are 'exceptional' isolated departures from the rules. They are more often than not heinous but not considered exceptional because of their extreme nature; they are not typical of the individual responsible for the 'active error'. Typically, when asked, individuals are left without an explanation for exceptional violations. However, they are often conscious of the possible consequences of their actions.	28	7.8

19 per cent (*n*68) of the reported injuries in the sample result from perception errors. They represent injuries sustained from disorientation resulting from prevailing environmental conditions and may largely be associated with working in Self Contained Breathing Apparatus (SCBA) during a critical activity when firefighters are more likely to be working remotely from

the influence and oversight of their supervisors. The analysis of Injured Party Experiences of Study 3 (Chapter 6) may provide evidence in support of this assertion.

It is also important to note the number of reported injuries resulting from a type of violation (12.5 per cent, n45). Whilst this is a relatively small number in comparison to skill and decision-based errors, this combined total represents injury resulting from intended action taken in full light of the knowledge that it is outside the normal expected behaviour. A supervisory regime or culture that allows 'work arounds' to cope with organisational rules and procedures enables routine violation (4.7 per cent, *n*17) to become normal behaviour (Dekker 2015). In contrast, exceptional violations are rare and more likely to occur in critical situations, almost twice as many reported injuries (7.8 per cent, *n*28) resulting from violation fall into this category.

Factors such as training, supervision and management can influence violation (Keith and Frese 2008) and are significant to any arrangements for the maintenance of competence. Descriptive data analysis of the AEDs identified in this sample brings FRS arrangements for the maintenance of competence sharply into focus.

4.3.1 Injury Profile.

When considering severity in terms of absence the relationship between severity of injury and error type makes a valuable contribution to understanding the psychological pre-cursors or HFs that in some way enable or influence the unsafe acts of firefighters and contribute to their injury at the moment-of-choice. This aspect of analysis considers severity of injury from three perspectives. Firstly, an indication of severity is determined by the number of days absence from a place of duty. This is further emphasised by the likelihood of the IP pursuing litigation because of sustaining injury. Severity is also explored by the level of investigation that occurred because of a reported injury.

The majority of injuries did not result in a loss of time from work (69%, *n*286). However, 9 per cent (*n*34) involved a time loss of up to seven days and the severity of a further 22 per cent (*n*91) met the criteria for reporting to the Health and Safety Executive (HSE) under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) (2013).

Table 4.2 Injury profile demonstrated by frequency of injury related variables.

Category		*n*	Not Given	Valid %
Absence			1	
	No Time Loss	286		68.6
	Up to 7 Days	39		9.4
	More than 7 Days	91		21.9
Litigation			34	
	Yes	9		2.2
	No	298		71.5
	Unknown at time of recording	76		18.2
Level of Investigation			2	
	Immediate Supervisor	97		23.4
	Line Manager	299		72.0
	More Advanced	19		4.6

At the time FRS data was provided for analysis, notification of the intention to pursue litigation had been made in n9 cases (2.2%). The number that it was believed would not be pursuing litigation was n298 (71.5 %), the remainder n76 (18.2%) were recorded as ‘unknown’ at the time of data entry. Included in the data are a further n16 (4%) injury cases that were recorded and reported because of an FRS policy for treating exposure to hazardous substances, smoke, heat or violent behaviour as an ‘operational injury’.

23.3 per cent (*n*97) of injury causing accidents were investigated by the immediate line manager of the IP and the next level of manager investigated 72 per cent (*n*299). More senior/qualified accident investigators of the relevant FRS investigated 4.6 per cent (*n*19).

Table 4.3 Injury profile demonstrated by crosstabulation with Active Error Descriptors.

Severity Variable	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
				Routine	Exceptional	
Absence						
No Time Loss	74	93	45	15	19	261
Less than 7 days	11	10	9	0	1	31
RIDDOR Reportable	24	32	13	1	8	79
						371
Litigation						
Yes	2	5	1	1	0	9
No	87	82	50	13	28	276
Unknown	15	35	12	1	0	63
						372
Level of Investigation						
Supervisor	30	20	21	2	0	74
Manager	77	114	44	14	25	288
More Advanced	3	1	1	0	3	8
						372

Variation in total counts demonstrated by crosstabulation relates to those cases where an AED was not provided by participating FRSs. However, represented by both absence (*n*292, 79%) and litigation (n285, 77%) the less severe injuries are in the majority. Reflecting the prevalence for decision (24, 38%) and skill-based errors (32, 50%), here they represent the majority of the more severe of reported injuries. Of equal importance is the number of the more severe injuries that result from procedural violation.

Table 4.4 Likelihood of Litigation and Level of Investigation represented by crosstabulation with Severity.

	No Time Loss	Less than 7 days absence.	More than 7 Days Absence	Total Count
Litigation				
Not Given	23	6	5	34
Yes	5	1	3	9
No	214	18	66	298
Unknown	44	14	17	75
				416
Level of Investigation				
Supervisor	78	13	5	96
Manager	201	21	77	299
More Advanced	5	5	9	19
				416

Based on severity of injury, both decision-errors (29.4%) and skill-based errors (36.4%) were the dominant cause of time loss injury. Most decision-based errors resulted in an absence from duty of less than seven days as did the majority of perception errors (29%). But most of the more severe injuries resulting in an excess of seven days absence were the result of skill-based errors.

Crosstabulation was also used to compare the relationship between the severity of injury and level of investigation, and the pursuit of litigation reported at the time of the study.

It would normally be expected that litigation has a direct relationship with severity where the more severe of injury causing accidents are likely to result in subsequent litigation. Crosstabulation of the litigation variable with severity revealed this not to be the case. Of the nine confirmed litigation cases in the study, five of the no time loss cases were confirmed to be pursuing litigation; there was also one with a severity of less than seven days absence; and contradicting the severity theory, only three RIDDOR reportable injuries. Of the 75 cases where the pursuit of litigation was unknown at the time of the study those with no time loss were also in the majority (*n*44, 57%).

It would also normally be expected that the level of investigation has a direct relationship with severity and that most no time loss injuries would be investigated and reported by the local supervisory level.   Once again, this is not the case. Crosstabulation revealed that of the 96 investigations conducted at the local level n78 (19%), involved no time loss injuries. However, 13 injuries resulting in less than seven days absence and five of more than seven days absence were reported as being investigated at the local level. Along with a more advanced level of investigation senior managers investigated a total of *n*206 (50%) no time loss injuries.

As with the Demographic profile no statistically significant difference was evident between the length of absence from duty, potential for litigation, and level of investigation ($x^2 = 13.398$, df = 10, p = .202). This is further evidence that the research focus of this study cannot be on the influence of one specific error type and whilst decision and skill-based errors continue to dominate, all five types of AED are common to accident causation.

Common causation theorising lends itself to determining the approximate ratio of near miss or no injury accidents that may be associated with the research sample. Common cause theory was introduced by Heinrich almost a century ago (Heinrich 1941) and established a ratio principle where for every major injury there was 29 minor injuries and 300 no injury accidents (near misses). Whether or not injury occurred, all three levels of severity had common and very similar causal patterns. The argument Heinrich developed was that it was in the largest groups where the most valuable clues to causation are found, which became known as the Common Cause Hypothesis (Toft et al 2012).

In recent years Heinrich's Law has been described as ‘superficial’ and a myth that should be dislodged from the practice of safety (Manuele 2011, Rebbitt 2014). Manuele's criticism focused on the relevance of ratios, and the suggestion that reducing accidents will reduce their severity. Rebbitt (2014) acknowledges that common cause hypothesis is about reducing the number of more serious accidents by reporting and investigating the more minor ones. Fundamentally, Heinrich states a simple case, that with similar causal features the key to understanding and developing accident reduction strategies lies in the larger number rather than the smaller.

The literature review of Chapter 2 established that an active error during emergency response operations that does not result in a reported injury is identifies as a ‘near miss’. Therefore, based on common cause theory, taking the most severe injury cases of the sample (more than 7 days), Heinrich’s inference (300:1) is that in the year of this study almost 7,200 near misses could have occurred because of a decision error, 9,600 from skill-based errors and 6,600 as a result of perception errors or some type of violation.

FRS arrangements for investigating and reporting near misses are not considered in this research and are excluded from the data set of this first study. What common cause theory does infer is that there is a continuum of severity based on consequence ranging from near miss to fatal injury which at the level of near misses, yet again introduces a cultural influence as depicted in the matrix of Figure 4.2 below.

Where fatal or life limiting injury occurs several agencies will be involved in investigation. The Police are required to investigate death in the workplace. The

Health and Safety Executive (HSE) will investigate to determine if a breach of duty has occurred. As the ‘employer’, the FRS has an obligation to investigate as well as comply with the requirements for reporting under RIDDOR. The representative body of the injured party will also conduct an independent investigation. However, at the time of this study neither Police, HSE, external or third-party investigations had been conducted into any of the injury causing accidents of the sample.

Included in the data are a further *n*16 (4%) injury cases that were recorded and reported because of FRS policy for treating exposure to hazardous substances, smoke, heat, or violent behaviour as an ‘operational injury’. Of these, exposure to hazardous substances has in recent years been known to result in post-retirement life limiting illness. In some cases, as with Post Traumatic Stress Disorder (PTSD) this may result from a cumulative effect and not lend itself to association with a specific event with an investigation history.

From the injury profile analysis, it can be seen that by measuring severity using absence from duty, the less severe of injuries are in the majority and are more likely to result from decision-based or skill-based errors, and procedural violation is likely to result in severe injury. In terms of using litigation as an indicator of severity of injury there is insufficient evidence to suggest a direct relationship exists between the pursuit of litigation and severity. Similarly, the level of investigation cannot be used as a reliable indicator of severity as there is no consistency across the participating FRSs in their accident investigation policies and whilst the more severe of reported injury is unlikely to be investigated by a local supervisor, the level of investigation is largely determined by individual FRS policy.

4.3.2 Demographic Preconditions.

This aspect of the study considers the demographic characteristics of age, length of service, and role of injured parties (IPs) reporting injury in the emergency response domain of the participating FRSs and compares them against the AEDs identified above. The importance of these three primary demographic factors lies in the way they can be used to represent experience, and therefore demonstrate if those with more experience are less likely to report injury.

The literature review of Chapter 2 establishes the influence of previous experiences on judgement and decision-making performance. The Naturalistic Decision Making (NDM) paradigm strongly argues that judgements and decisions are influenced by experience(s) and places great emphasis on the influence of expertise in decision making, in particular during risk taking behaviour. Both the Normalistic and Naturalistic decision-making paradigms hold the view that judgements and decisions are influenced by experience(s) and those *"of a rookie firefighter would be far less accurate than those used by a commander with 20 years of practice"* (Klein, Calderwood and Clinton-Cirocco 2010, Flin et al 1997:13).

Experience is also considered to be inherent to the development of competence (HSE 2018, Okoli, Watt & Weller 2017, Paloniemi 2006). Consequently, scrutinising AEDs against the frequencies and descriptive statistics of demographic variables provides important evidence relating to the experience component of competence at the 'moment-of-choice'.

Firefighters are judged competent in their role when they have demonstrated they have the knowledge, skills and understanding to perform effectively. The point at which a firefighter is first considered to be competent varies between FRSs. FRSs participating in this study identified this to be between three and five years. For this analysis this threshold is accepted to be five-year's service. Table 4.2 below presents a comparison of the mean distribution of demographic variables and includes a crosstabulation of injury history by Role.

In terms of IP gender, the sample of 417 injury cases comprised of *n*380 men and *n*37 (8.9%) women. In the reporting period under scrutiny (2015/16), the number of women firefighters in England was recorded as being 'approximately 1,800' (5%), (Home Office 2021). Although it was obtained, IP gender was excluded from separate data analysis initially based on the low numbers of women IPs. The rationale for this stance is further substantiated by role descriptions in the FRS which do not demonstrate a gender difference in the competence requirements at any role level. *"Whether male or female the role map of a Firefighter through to Brigade Manager (Chief Fire Officer) is without gender variation"* (Gough 2019:154). So too do male and female entrants have to meet the same physical standards for entry into the same FRS. Reinforcing this research approach, limited empiric research exploring the influence of gender difference and firefighter injury was found in the literature.

Qualitative research into injury of female firefighters conducted in North America was found to be polarised. Hollerbach et al (2017) found that despite the physiological differences between males and females largely relating to upper body strength; *"…experiences with injury types and rates were similar across genders",* (Hollerbach et al, 2017:4). In another study focusing on the experiences of female firefighters Sinden et al (2011) concluded that physical and psychological stressors expose female firefighters to an increased risk of injury (Sinden et al, 2011). More recently an international study of the health and well-being of women firefighters concluded that *"There is a need for female-specific strength and conditioning support and facilities to decrease injury and illness risk"* (Watkins et al, 2019:424). What these studies do have in common is the way they expose cultural influences on the attitudes and behaviours of female firefighters to risk of injury and its reporting. Whilst some aspects of cultural influence are considered in Study 3, broader commentary on cultural influence is captured in the general discussion of Chapter 7 below.

Consequences of an Active Error with common or similar causal patterns.						
Where no physical injury occurs but the culture of the group adopts a title or 'nick name' for the actor(s) involved. To avoid becoming a victim of such 'stigma' the event and injury may go unreported. When reported a near miss should be investigated and causation established.	Physical injury has occurred only requiring first aid treatment. The circumstances have been reported but do not warrant the Injured Party being absent from their place of duty. An accident investigation will identify and report causation of all reported injury.	Physical injury has occurred and been reported resulting in the Injured Party taking time off duty. Medical consultation and treatment may also have been sought in order to qualify for Statutory Sick Pay at the next consequence threshold.	In these circumstances injury has been so severe that the Injured Party is unable to return to duty without clinical intervention. May result in medical discharge	As a consequence of the more severe circumstances of injury, the Injured Party may incur a life-time disabling injury.	Circumstances where the longevity and normal life span of an Injured Party are shortened.	Injury sustained at the 'moment-of-choice' is proximally fatal.
Near Miss	No Time Loss	Less than 7 days Absence from Duty	More than 7 days Absence from Duty	Life Changing	Life Limiting	Fatal

Figure 4.2 The continuum of consequences resulting from Active Errors in the Emergency Response Domain of the FRS.

In terms of age, IPs demonstrated quite some life experience (M 40.72, SD 8.7) and whilst age increases with role so too does the frequency of injury increase with age where those IPs reporting injury more than twice are the more mature IPs of the sample (M 42.9, SD 8.2). Many IPs had previously reported injury (68%), 45% on multiple occasions. Amongst that number, four had reported being injured in excess of 10 times.

The experience of all IPs far exceeds the five-year competence threshold (M14.55, SD 7.8), and only 10% of IPs in the study had less than five-year's service. Both age and experience of IPs increases exponentially with role, but the experience of IPs in the role of firefighter continues to exceed the five-year competence threshold (M 13.8, SD 7.68).

Given the importance of experience to the acquisition of knowledge and skill, analysis of variance (ANOVA) was conducted to determine if any specific active error type could be associated with the length of service of an IP. Knowledge that skill-based errors are more likely to be the cause of injury to IPs with less than five years-service would be a normal expectation. However, in the case of IPs that exceed the five year threshold such knowledge would be significant not only to researchers but would also have relevance to FRS arrangements for the maintenance of competence. No significant difference was found between experience measured by length of service and active error type: (F (5, 364) = 0.194, p = .635, n^2_p = .009).

Based on the evidence that the likelihood of injury increases with age and the frequency of injury reporting also increases with age, ANOVA was also conducted to determine if a specific error type could be associated with IP age. Being able to identify if the more mature IPs are given to routine violation resulting from habit, or skill-based errors are more likely to be the cause of injury in the younger age group, would have similar significance to researchers and FRSs as that of experience above. Once again, no significant difference was found between age and active error type: F (5, 362) = 62.5, p = .514, n^2_p = .012).

That no statistically significant difference was evident between age or length of service and error type is a strong indication that the research focus on the demographic aspects of this study cannot be on the influence of one specific error type. In terms of age and experience, all hold equal importance.

Table 4.5 Comparison of Mean distribution of Demographic variables including crosstabulation of Injury History by Role.

Variable Category	Count	%	Experience M	Experience SD	Age M	Age SD
Role						
Firefighter	314	75.7	13.84	7.68	39.65	8.79
Crew Manager	58	14	14.7	7.06	42.48	7.7
Watch Manager	41	9.9	19.02	7.98	45.5	7.4
Senior Manager	2	0.5	25.5	4.95	50.5	3.56
Missing cases	2					
Totals	417		14.53	7.79	40.71	8.71
Injury History						
First Reported Injury	123	31.9	14.4	8.43	39.07	9.09
Injured Once Before	86	22.3	12.63	7.23	38.4	7.88
Injured more than twice	177	45.9	15.99	7.19	42.89	8.19
Missing Cases	31					
Totals	417		40.71	8.71	40.68	8.64

Crosstabulation of Injury History and Role	First Reported Injury		Injured Once Before		Injured more than Twice	
	Count	%	Count	%	Count	%
Firefighter	92	74.8	65	75.5	135	76.2
Crew Manager	18	14.6	12	13.9	24	13.5
Watch Manager	10	8.1	9	10.4	17	9.6
Senior Manager	1	.	0	.	1	.

The frequency of reporting injury increases with both age and experience but diminishes with role, the vast majority (75%) being reported by firefighters. This reflects the role differences during tactical operations where, when implementing the requirements of the Incident Commander's tactical plan, unsupervised firefighters are more likely to be acting under their own judgement and decision making. This is more likely to occur in fires than in non-fire incidents and is more common to incidents involving the entry of firefighters in SCBA for search, rescue, and firefighting. Assumption of competence of those entering this environment is the norm, and it is more likely that those involved will be the first to encounter unexpected and unforeseen circumstances.

There is also consistency of repeated reporting across the three frequency of injury categories. However, it is evident that firefighters are more likely to report injury on frequent occasions and reporting of injury is less likely to occur when an IP holds a more senior position. As with gender variation in reporting injury, this too may have a cultural influence. A socio-cultural influence may also influence the low number of injuries reported by firefighters in the early years of their career. The potential influence of culture on injury reporting is further considered in the discussion of Chapter 7 below.

4.3.3 Temporal Preconditions.

National Fire Statistics for England (Home Office 2019) only provide temporal data for fires and fire related casualties by time of day and month. The annual report of firefighter injuries (Home Office 2021) offers no temporal data that might indicate seasonal variation, variation based on shift patterns, or variation arising from the time of day/night injury is occurring. Known to all FRSs when injury is reported, these data are captured in this study to explore the relevance that these variables may have to accident causation. Of particular interest is the potential for reported injury to be greater towards the end of a shift or period of duty than the beginning which may suggest an element of accumulated fatigue.

Between the participating FRSs six different and nuanced shift patterns were reported. These were first rationalised to either the whole-time duty system (WDS) of 24 hour availability and the on-call or retained duty system (RDS) of response when needed. Time of day was first generalised for the purpose of analysis into six categories of four hour intervals. This was then further generalised to generic periods which capture injuries occurring during the daytime hours of 08:00 – 19:59, or night-time hours of 20:00 – 07:59.

National Fire Statistics for England (Home Office 2019) provide temporal data for fires and fire related casualties by time of day and month. The number of fires recorded by time of day in the year of the study indicates that the largest percentage (31%) occurred in the late afternoon/early evening period 16:00-20:00. This is reflected in the result of the frequencies analysis of table 4.2 which is based on all 417 reported cases in the study, where the largest number of injuries were also reported in the same time period (27.5%).

Temporal data including time of day of non-fire incidents is specific to road traffic collisions (RTCs) (Home Office 2019), and indicates that as with fires, the highest percentage (25.4%) also occurred in the late afternoon/early evening period. A test of association between the late afternoon/early evening period 16:00-20:00 (based on 369 valid reported cases of the temporal data set), and AEDs established a significant association (x^2 = 54.36, df = 25, p = .001). Crosstabulation also revealed the majority (n18, 64%) of exceptional violations occurred in the period when the change of shift between day and night crews also occurs. Closer examination of crosstabulation

Table 4.6 Frequency of injury occurrence by chronology and shift pattern.

Category		*n*	Not Given	Valid %
Time of Day		416	1	
	00:00 - 03:59	40		9.5
	04:00 - 07:59	38		9.1
	08:00 - 11:59	69		16.4
	12:00 - 15:59	93		22.3
	16:00 - 19:59	114		27.5
	20:00 - 24:00	62		14.9
Day of Week		417		
	Monday	41		9.8
	Tuesday	91		21.8
	Wednesday	65		15.6
	Thursday	55		13.2
	Friday	36		8.6
	Saturday	65		15.6
	Sunday	64		15.3
Month		416	1	
	January	20		4.8
	February	30		7.2
	March	35		8.4
	April	35		8.4
	May	36		8.7
	June	37		8.9
	July	58		13.9
	August	36		8.7
	September	37		8.9
	October	34		8.2
	November	29		7.0
	December	29		7.0
Rota/shift at time of Injury		391	26	
Whole Time working a shift pattern of consecutive days based on 2 Days followed by 2 Nights	First Day	111		28.1
	Second Day	91		23.3
	Third Day	1		0.3
	First Night	65		16.6
	Second Night	55		14.1
Retained	Day	24		6.1
	Night	16		4.1
Generic Shift		391	26	
	Day	244		62.4
	Night	147		37.6

based on hourly intervals revealed that the majority of these (*n*12) were reported to have occurred between 19:00 and 20:00.

In terms of the weekday on which injury is occurring there is no national statistical comparison. This study identified the greater number of reported injuries occurred on Tuesday (*n*82, 22%), which included the larger proportion of all decision errors (n29, 26%), and violations (*n*44, 45%). 56% of all injuries being reported occurred in the middle of the working week (Tuesday-Thursday). A test of association between the day of the week on which injury was reported to have occurred and AEDs established a significant association (x^2 = 72.54, df = 30, p = .001).

Table 4.7 Frequency distribution represented by crosstabulation between the shift being worked and Active Error Descriptors.

Time Categorised as Four Hour Intervals	Exposure Policy	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
					Routine	Exceptional	
Midnight - 03:59	0	12	15	5	0	1	33
04:00 - 07:59	0	10	14	8	2	0	34
08:00 - 11:59	2	19	27	10	2	5	65
12:00 - 15:59	0	24	27	21	3	3	78
16:00 - 19:59	8	30	24	17	4	18	101
20:00 - 23:59	5	15	27	5	5	1	58
AED Total	15	110	134	66	16	28	369

In terms of monthly comparison, national statistics for England (Home Office 2019) identifies that fire incidents were at their highest in April (591) and their second highest in June and July respectively (547). Whilst the frequency of reported injury in April and June reflects the annual mean of the study (34.6), reported injury almost doubled in July (*n*58, 14%) suggesting a seasonal influence on the propensity for reporting injury.

For the year of the study the Met Office reports that much of lowland England received below average rainfall and that April and June were dry months across England (Met Office 2016:23). Little rainfall from spring through summer 2015 resulted in 22,100 fires of various size involving grassland, woodland and crops which was an increase of 14% on the previous year. These were occurring at the rate of 138 per day in April, and 111 and 132 per day respectively in June and July (Home Office 2019). Environmentally, this type of firefighting would be conducted in conditions of heat and humidity which would lead to fatigue and dehydration. Whilst the environmental data provided by participating FRSs is limited, it is also relevant and is captured and reported in the Environmental Preconditions section that follows.

Table 4.8 Frequency distribution represented by crosstabulation between the shift being worked and Active Error Descriptors.

Rotation at Time of Injury	Exposure Policy	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
					Routine	Exceptional	
First Day	12	28	23	24	1	9	97
Second Day	1	32	27	11	4	13	88
Third Day	0	0	1	0	0	0	1
First Night	1	17	32	11	2	1	64
Second Night	1	15	21	7	6	3	53
FDS Night	0	0	1	0	0	0	1
Retained Day	0	7	9	5	0	0	21
Retained Night	0	6	7	3	0	0	16
Variant Day	0	1	0	0	0	0	1
Variant Night	0	0	0	1	0	0	1
Day Crewing Day	0	0	2	0	0	1	3
Day Crewing Night	0	0	0	1	1	1	3
24 Day	0	1	5	1	1	0	8
24 Night	0	1	2	1	0	0	3
AED Total	15	108	130	65	15	28	361

Injury is more likely to be reported during the commencing day duties of the shift pattern being worked, with 28% (*n*111) occurring on the first day of duty. The relationship between the shift patterns being worked by IPs indicates that almost twice as many injuries are reported to have occurred during the generic daytime period (08:00-19:59) than at night.

Crosstabulation revealed most of the reported injury of the WDS occurred on the first day shift (*n*97, 27%). But almost an equal amount (*n*88, 24.3%) occurred on the second day shift when most exceptional violations also occurred (*n*13, 72%). However, crosstabulation also revealed that many reported injuries were occurring on the first (*n*64, 18%) and second (*n*53, 15%) night shift. Where the RDS was concerned, slightly more (*n*21) injuries were reported to have occurred during the generic daytime period than night-time (*n*16). A test of association between the shift patterns being worked by an IP at the time of reported injury and AEDs established a significant association (x^2 = 94.75, df = 70, p = .026).

The most statistically significant of temporal preconditions lies in the number of reported injuries occurring in the generic daytime period specifically associated with the late afternoon/early evening 16:00 – 20:00 period. It is also in this period that the greater number of exceptional violations are occurring. This being the period which would capture the normal WDS change of duty shift from day crew to night crew working, raises the potential for socio-cultural behaviours focussed on withdrawing from an incident and returning home later than normal to be worthy of closer scrutiny. There is no significant evidence to suggest that reported injury is greater towards the end of a complete shift rotation or period of duty than at the beginning. Therefore, the influence of accumulated fatigue arising from several duty shifts is unlikely to be the case.

4.3.4 Environmental Preconditions.

No national statistics are published that complement data relating to the four environmental variables sought during the study. Consequently, it is this data set that demonstrates the greater proportion of missing data. That it has no national significance largely influences the lack of data provided by participating FRSs. However, the relevance of the prevailing environmental influences acting as preconditions of accident causation increases with injury severity.

Generic environmental preconditions at the time of injury relating to the surface on which an IP was working, the condition of the ground, climate and visibility were sought. The levels of participant response demonstrated that the least frequently considered of the four variables were represented by the lowest numbers. Case study data was provided for *n*153 (37%) surface, *n*146 (35%) ground, *n*235 (56.3%) climate, and *n*367 (88%) visibility. At 14% of the total number of injuries reported in the year of the study, data relating to surface conditions and ground conditions are not treated as a sample on which results can be generalised. They are instead used in general discussion and further considered in the summary discussion below.

The results on seasonal variation analysis in section 4.3.3 above described how in the year of the study there had been little rainfall from spring through much of summer. Over 22,000 fires of various size involving grassland, woodland and crops occurred. At the height of summer this was at the rate of 132 per day (Home Office 2019). The surface conditions of this kind of terrain are difficult underfoot resulting in slips, trips, and falls. In turn these would result in an increase in sprains and strains. 36% of reported injuries occurred when the IP was working on an uneven, overgrown, steep, or sloping surface typical of fires involving grassland, woodland, and crops. These kinds of working conditions are known to be physically demanding, stressful and cause fatigue which in turn is known to affect judgement and decision-making and lead to skill degradation (Sharit 2012).

Table 4.9 Frequency of limited data relating to the environmental preconditions at the time injury occurred.

Category	*n*	Not Given	%*	Valid %
Surface Conditions		264	46	
Wet	38		9.1	24.8
Dry	11		26.3	71.9
Indoors/fire compartment	2		0.5	1.3
Debris	0			
Ground Conditions		271	65	
Sloping	13		3.1	8.9
Flat	93		22.3	63.7
Steep	1		0.2	
Overgrown	6		1.4	4.1
Uneven	33		7.9	22.6
Weather Conditions		182	43.6	
Rain	38		9.1	16.2
Snow	1		0.2	
High Wind	4		1	1.7
Hot/Dry/Warm	173		41.5	73.6
Cold	17		4.1	7.2
Fog	2		0.5	
Visibility		50	12	
Light	165		39.6	45.0
Normal Street Lighting	78		18.7	21.3
Torchlight	25		6	6.8
Scene Lighting	42		10.1	11.4
Dark	57		13.7	15.5

**The first percentage figure is set against the total sample of 417 cases, the valid figure against the limited data of the 153 cases in the analysis.*

Although not generalisable to these conditions, the larger proportion of reported injuries occurred when weather conditions were hot/dry/warm and surface conditions were also dry (≈77%). Whilst firefighting in the heat and humidity of summer temperatures would lead to fatigue and dehydration, the added dimension of ground conditions common to many grass and woodland fires highlights the physically demanding nature of seasonal firefighting.

Given that fatigue can influence decision and skill-based errors the association between AEDs and all four environmental variables was tested. Variables with a low frequency count of two or less were not captured by crosstabulation. These included surface conditions described as indoors or in a fire compartment and where debris was present; steep ground conditions; and during snowfall. Crosstabulation also only captures those cases where a corresponding AED was recorded.

Although only a small sample was compared, the relationship between surface conditions and AEDs demonstrates that the larger proportion of reported injuries can be associated with dry conditions. It is also the case that whilst decision and skill-based errors are prevalent in both wet and dry conditions, most perception errors are associated with dry conditions. Analysis revealed no statistically significant association between surface conditions and AEDs (x^2 = 5.53, df = 5, p = .355).

Once again, the ground conditions category is represented by a small sample (*n*133) and reveals that the larger proportion of reported injuries can be associated with flat ground conditions where once again, decision and skill-based errors dominate. As with surface conditions, there was no statistical significance in the association between ground conditions and AEDs (x^2 = 20.8, df = 15, p = .143).

The weather category is represented by a larger sample and clearly demonstrates how the vast proportion of reported injury can be associated with hot weather (*n*148, 70%) where all five AEDs are represented. Reflecting the principal of skill degradation and the affect hard working conditions of hot weather can have on judgement and decision-making, skill-based and perception errors account for a large proportion. More noticeable are errors resulting from violation with the majority being associated with exceptional violations. Although analysis revealed no statistical significance in the association between weather conditions and AEDs, the p value was found to be close to the level of significance (x^2 = 29.62, df = 20, p = .076).

Table 4.10 Frequency distribution represented by crosstabulation between Environmental variables and Active Error Descriptors.

Environmental Variable	Exposure Policy	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
					Routine	Exceptional	
Surface Conditions							
Wet	0	12	12	7	0	0	31
Dry	6	28	22	22	4	1	83
	6	40	34	29	4	1	114
Ground Conditions							
Sloping	0	7	5	2	0	0	14
Flat	6	30	33	12	3	1	85
Overgrown	0	2	1	3	0	0	6
Uneven	0	7	8	13	0	0	28
	6	46	47	30	3	1	133
Weather							
Rain	0	11	13	11	0	0	35
High Wind	0	2	2	0	0	0	4
Hot	11	32	48	19	13	25	148
Cold	0	7	6	4	0	1	18
Fog	0	1	1	0	0	0	2
	11	53	70	34	13	26	207
Visibility							
Light	10	36	55	21	6	9	137
Street Lighting	0	26	15	15	5	15	76
Torchlight	0	4	8	10	2	0	24
Scene Lighting	0	10	20	8	0	1	39
Dark	3	14	26	5	1	2	51
	13	90	124	59	14	27	327

The final category of environmental precondition is visibility and is represented by a much larger sample of the study (78%). Clearly, the vast proportion of reported injuries occurred during normal daylight conditions (*n*137, 42%) and the second largest proportion under normal street lighting. Of note are perception errors where of the 59 in the analysis more than half (55%) occurred in artificial lighting condition. Perception errors are more prevalent when using torchlight which is an important item of equipment used by firefighters when wearing SCBA. Given the proportion of the study that this category sample represents, this would support the assumption that reported injuries occurring whilst the IP is indoors or in a fire compartment remains valid. Whilst the prevalence of decision and skill-based errors continues, analysis revealed the association between visibility and AEDs to be statistically significant (x^2 = 54.86, df = 20, p = .001).

As a relevant precondition to active error and accident causation, this data set has the greater proportion of missing data. That which was provided is biased towards weather and visibility. This could be largely due to individual FRS practice where proforma's used for collecting data for post-accident investigation have a similar bias. This is not to assume that the environmental information was not available at the time of the study, more that it was not readily available to the managers participating in this data gathering process. This analysis has revealed that there are environmental preconditions that are worthy of more attention, but it remains that because it has no national significance, FRSs are unlikely to give it the attention it quite clearly deserves.

Whilst decision and skill based errors dominate throughout the analysis, the larger frequency of reported injury occurred in relatively inert environs of normal daylight conditions where the surface on which the IP was working was likely to be dry and the ground flat. A slightly larger proportion of reported injury occurred during the need for artificial lighting conditions when the IP may be working in darkness or smoke during firefighting operations and wearing SCBA. However, the frequency table indicates only two reported injuries occurred whilst the IP was indoors or in a fire compartment which should exclude this assumption but with 264 missing cases, the assumption remains valid.

Working in hot weather can influence judgement and decision-making, and a large number of perception errors are associated with dry conditions. Similarly, more than half of perception errors occurred in artificial lighting condition. Perception errors were also more prevalent when an IP was working in torchlight which may indicate that at the 'moment-of-choice' they were working in hot environmental conditions whilst wearing SCBA. In the application of Recognition Primed Decision-making (RPD) a decision maker must be able to recognise which environmental cues are important, flawed perception will influence their ability to make sense of their situation and assess the course of action most likely to succeed.

Although based on a limited data sample the combined evidence from the temporal and environmental preconditions analysis of association with AEDs exposes a relationship between seasonal influences and reported injury. The final analysis that follows considers the contextual preconditions of active error and may further support this relationship.

4.3.5 Contextual Preconditions.

It is generally accepted that erroneous behaviour is affected by the context in which it occurs (Leveson 2017, Norman 1981, Rasmussen 1997). Contextual preconditions create some of the most powerful cues in the emotionally charged, rapidly changing, information limited, and time constrained environment of the emergency response domain of the FRS. They are known to influence behaviours and will place firefighters at the mercy of cognitive and situational factors.

Of all the contextual cues that can influence the 'moment-of-choice' of firefighters the most powerful is the expression 'persons reported'. Often known at the commencement of the response phase of an incident, these are circumstances where life is known to be immediately at risk and its influence becomes even more powerful if children are involved. This emotional contextual cue is not unique to fires and firefighting, it also applies to a wide range of non-fire incidents. The expression ‘persons reported’ can apply to victims trapped in vehicles following a road traffic collision; by floodwater; in building collapse; collapse of groundworks; as well as being trapped in or by heavy plant and industrial machinery. Further adding to the emotional context, there is an expectation that when dealing with ‘persons reported’, regardless of the incident context “*where lives are in danger and the benefit of saving life is high, then a higher risk to firefighters may be accepted”* (NOG 2021g).

In the analysis of contextual preconditions that follows two generic variables are examined. Firstly, the incident type which in addition to fires explores several different types of non-fire incident associated with reported injury in the sample. The second category sets out to identify the domain in which injury was reported to have occurred identified by four categories, response; in attendance; during critical activity; and in what is described as the post incident phase, the boundaries of which are explained in the descriptive analysis that follows.

It is important to note that in gathering incident type data, information relating to the ‘persons reported’ cue was not overtly sought. Participating managers were instead requested to identify if the activity of the IP at the time of injury was of a critical nature which is defined in this research as *“circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome”.* This would be circumstances such as the rescue of a victim from fire or life-threatening entrapment. It is these that involve many cognitive influences and a more overt risk of injury.

An important aspect of the contextual preconditions analysis is that it is limited to a little over half (53%) of the reported injury cases captured by the study. The sample indicates the majority of injuries occurred whilst responding to or attending fires (68.4%) rather than non-fire incidents. This compares closely with the national report for the year 2015/16 (66%) (Home Office 2021), which would suggest it represents an indicative sample on which valid judgements can be made. A significant number (36% *n*149) also occur in the domain of responding which includes all injuries sustained from the time of call but before arrival at the incident location some of which result from road traffic collisions involving the responding appliances and vehicles and may have been influenced by the ‘persons reported’ cue.

Table 4.11 Frequency relating to the incident context and domain in which injury occurred.

Category		*n*	Not Given	Valid %
Incident Type			196	
	Fire	151		68.4
	Road Traffic Collision	40		18.1
	Water	3		1.4
	Hazmat	4		1.8
	Special Service (not specified)	15		6.8
	Animal	8		3.6
Injury Domain				
	Responding	149		35.7
	In Attendance	142		34.1
	During Critical Activity	93		22.3
	Post Activity	33		7.9

In the year of the study 858 accidents involving FRS vehicles were recorded when using blue lights for emergency purposes. 808 of which involved responding fire appliances (Home Office 2019). These are circumstances where injury can be sustained by some or all of a crew which could account for as many as 6 injury cases for one event. Data provided for this study indicates that of the 18 participating FRSs

12 blue light accidents occurred resulting in 43 reported injuries, 10 of which involved fire engines. Representing a 40% sample of all English FRSs, this would indicate that the vast majority of 858 reported vehicle accidents (≈88%) occurring under blue lights may not have resulted in reported injury.

The remaining 106 (25%) of responding injuries occur at the point of call out within the fire station environment when responders are making their way to their appliances or vehicles. These injuries involve slips trips and falls or cuts and bruises sustained on the route taken between rooms, vehicle locations and mounting fire appliances. Some of these may also be influenced by the ‘persons reported’ cue.

The attendance category includes all injuries sustained once the appliance or vehicle in which the IP was travelling has formally recorded attendance at an incident with the mobilising centre but before the IP was tasked to a critical activity. It is in this domain that the majority of reported operational injuries occurred (64% *n*268). These too would involve a similar range of injuries to those identified above some of which would be musculoskeletal injuries resulting from lifting and carrying heavy equipment from an appliance to a specific task location. Many such tasks may also involve a degree of urgency and may once again have been influenced by the ‘persons reported’ cue. Amongst the injuries reported to have occurred at an incident a small number (n25) were reported in compliance with FRS policy for treating exposure to hazardous substances, smoke, heat, or violent behaviour as an operational injury.

Whilst most injuries occur when the IP is at the scene of an incident, only 25% (*n*93) were associated with a critical risk -v- benefit decision making choice. This descriptor was used to capture generic IP activities that would add emotionally charged, rapidly changing, information limited, and time constrained context to the task activity with the potential to influence situational awareness and sensemaking at the 'moment-of-choice'.

Only a small number (*n*33) of injuries were reported to have occurred in the post activity phase of an incident. However, these occur when hazards and risks have receded or are arguably under control when activities focus on damping down and turning over at the incident location with view to returning responsibility for safety and security to a responsible person. Also included in this phase is the process of recovering and re-stowing equipment on appliances. This post activity group would also include injuries sustained in the process of returning to either an original or other designated response location or before receipt of another call during the journey which may once again involve vehicle accidents.

The total count of cases in the following analyses of association are based on those cases where an AED was provided by the participating FRSs. In the case of incident type this is limited to 46.5 percent of the sample, and injury activity 89 percent. This in itself is significant in that all of the participating FRSs record both the incident type and IP activity at the time of injury in their initial accident reporting/investigation process.

The evidence of crosstabulation represents a similar distribution of categories as the frequency table above, as such, for the purpose of this analysis it can be taken as indicative evidence of association. The prevalence of decision and skill-based errors continues but the low injury reporting rate associated with Hazardous Materials incidents is worthy of note. Whilst this is largely due to the levels of risk assessment, control measures and specialised skill and equipment necessary at such incidents, of some significance is that the only reported injury cases captured by the analysis result from violations. Important to the FRS involved, one was determined to be a routine violation which would indicate the need to revise procedure or examine the socio-cultural influences on those involved.

Of equal importance is that the non-fire incidents (*n*55), are more likely to be managed by supervisors with direct oversight of activities unlike fires where firefighters are more likely to be working remotely from their supervisors and commanders. A test of association between the type of incident where injury was reported to have occurred and AEDs confirmed a significant association (x^2 = 133.1, df = 25, p = .001).

Table 4.12 Frequency distribution represented by crosstabulation between Incident Type variables and Active Error Descriptors.

Incident Type	Exposure Policy	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
					Routine	Exceptional	
Fire	5	42	59	31	2	0	139
RTC	0	18	9	2	1	1	31
Water	0	0	1	2	0	0	3
Hazmat	0	0	0	0	1	1	2
SSC	6	1	3	0	0	1	11
Water	0	4	2	2	0	0	8
	11	65	74	37	4	3	194

The crosstabulation cases of the injury activity analysis also represents very similar distributions as those recorded in the frequency table above. Common to all analyses, decision and skill-based errors dominate. It is also worthy of note that the injury count diminishes with injury activity domain.

Of particular significance are the numbers of reported injuries occurring in the response phase of an incident and as with the incident type, these include a large number of violations. Given the description of the domain that these represent it is likely that the majority occurred whilst appliances were mobile to an incident. It is also likely that a proportion of these would involve the 'moment-of-choice' of an appliance driver and the added contextual precondition of 'persons reported'.

Table 4.13 Frequency distribution represented by crosstabulation between Injury Activity variables and Active Error Descriptors.

Injury Activity	Exposure Policy	Decision Error	Skill Based Error	Perception Error	Violation		Total Count
					Routine	Exceptional	
Responding	5	34	34	28	11	20	132
In Attendance	9	38	55	19	1	1	123
Critical Activity	0	27	37	13	3	7	87
Post Activity	2	11	9	7	1	0	30
	16	110	135	67	16	28	372

Further significance lies in the number of injuries reported to have occurred once the IP had arrived at an incident but before exposure to the increased risks of a critical activity. Whilst this captures most cases involving FRS exposure policies distribution across the AEDs indicates that this is the domain where the larger proportion of skill-based errors are resulting in reported injury. Whilst it would be acceptable to associate slips, trips and falls occurring when IPs are negotiating an incident topography with perception errors, the large proportion of skill-based errors are likely to involve equipment handling and use. The number of decision errors also demonstrate that this is the domain where, as a consequence of flawed situation awareness more mistakes are made.

Reported injury arising from a critical activity is worthy of closer scrutiny. Firstly, of the 93 cases in the data set, crosstabulation captures the majority (*n*87, 93%) and can be taken to be a representative sample for evidence of association. Secondly, in meeting the definition of this criteria it is implicit that those involved undertook a task/situation assessment and identified that despite the high level of risk involved, the benefit of achieving the desired result far outweighed the attendant risk(s). It is this cognitive process that represents the 'moment-of-choice'. This is where previous environmental and contextual experiences merge with the proximate characteristics prompting cues and influencing choice, circumstances that prime responses.

A test of association between the injury domain where injury was reported to have occurred and AEDs confirmed a significant association (x^2 = 46.47, df = 15, p = .001). However, given that the critical activity domain represents those circumstances where the risk of injury was realised, a further test of association was conducted to determine severity of injury type with incident type.

Table 4.14 Frequency distribution represented by crosstabulation between Incident Type variables and Severity of Injuries.

Incident Type	No Time Loss	Less than 7 Days	More than 7 Days	Total Count
Fire	17	3	3	23
Non Fire	11	4	2	17
	28	7	5	40

The rationale for grouping all non-fire incidents into a single category is based on the proposition that collectively, they represent supervised activities, whereas the fire domain is more likely to represent unsupervised activity. It should be emphasised that due to the number of critical activity cases that did not have a level of severity provided by participating FRSs the analysis can only be taken as inferential and not a true representation of the association that may have existed at the time of the study. Consequently, there was no statistical significance in the test of association between the type of incident where injury was reported to have occurred and severity of injury (x^2 = 4.87, df = 8, p = .772).

Another important observation from crosstabulation in table 4.13 is that in both incident type categories the minority of reported injury was also minor in nature and did not result in time loss. It should also be noted that the more severe of reported injuries associated with both incident types are almost equally distributed across each category. This would indicate that the critical injury activities of IPs are no more severe at fires than non-fire incidents.

Based on the type of incident being attended, whether it includes the heat and smoke of the confines of a burning building, the sometimes visual/audio demanding circumstances of victim entrapment, or the challenges of rapidly flowing floodwater, contextual preconditions have a direct impact on cognitive demand. They represent the 'what, so what, and what next?' (Golightly et al 2010) that characterise the three levels of situational awareness (Endsley and Jones 2012), although influenced by the environment they are in turn influential to the decision making context of the 'moment-of-choice' and are further discussed in the summary discussion that follows.

4.4 Study 1 Data Capture – Summary Discussion.

This study set out to better understand several variables associated with frequency and inform the answers to RQ1 and RQ2. It takes a closer, analytical look at a sample of reported injuries in the emergency response domain of the FRS occurring between 1st April 2015 - 31st March 2016 on which results have been generalised an overview of which is provided in Table 4.15 below. The results also represent the first time such a meta-analysis has been conducted with the purpose of seeking to better understand the preconditions of accident causation and their potential influence at the 'moment-of-choice'.

Table 4.15 Providing an overview of Study 1

Research Question(s)	Overview	Participation
Primarily RQ1 and RQ2 but use of AEDs also contributes to RQ3	Primary area of interest is the 'moment-of-choice' of injured parties (IPs). Study examines reported operational injury data held by English FRSs for the reporting year of 2015/16. Focus is placed on data relating to demographic, temporal, environmental and contextual variables held by FRSs but not included in the annual report to Home Office and not normally shared with others. Relevant to competence, demographic variables are examined to determine the influence of acquired experience. Injury severity variables are explored for the relationship between severity and error type. Temporal variables are used to determine if an element of fatigue could have been involved. Context variables are examined to determine if there is any significant relationship between activity and active error. The study establishes an 'error typing' taxonomy of Active Error Descriptors (AEDs) with the potential for adaptation as a component of an FRS Human Factors (HF) analysis framework (HFAF).	18 FRSs which includes evidence relating to 417 reported injury cases representing 40% of those included in the Home Office (2021) report for the year of interest (2015/16).

The data capture study represents an initial exploratory study and does not use complex statistical analysis techniques to probe the characteristics that represent the preconditions of accident causation. Instead, inference is drawn from tentative evidence of comparison of frequency of distribution and any relevant identifiable associations. The independent variable used in the test of association is that of an Active Error Descriptor (AED) which, for the process of error typing, was derived from the classification of unsafe acts (Reason 1990). AEDs are used to identify if the unintended outcome of the 'moment-of-choice' could be attributed to a decision based; skill-based; or perception-based error; or a particular type of violation influenced by the preconditions existing at the time.

The AED judgements were made by participants representing the role of subject matter expert (SME) of 18 FRS that provided 417 reported injury cases from the 1049 reported to have occurred in the year of the study. However, in 56 cases, the data was not amongst that provided by some of the participating FRSs, consequently, the AED analysis was based on 361 cases. Analysis demonstrates how the greatest number of cases involved either a decision based or skill-based error, AEDs that dominate throughout the analysis.

Decision errors occur when a normal and well-practiced sequence of events is out of sequence or mistimed. They can be the result of failing to fully understand information and how to use it such as memory failure represented by omission or simply losing the place in a planned sequence of actions. Decision-based errors represent a decision makers failure to fully understand their situation and are largely the result of a lack of situation awareness which is defined as *"being aware of what is happening around you and understanding what the information means to you now and in the future"* (Endsley and Jones 2012:13). Whether the slip of mistiming or lapse of memory, decision errors expose the knowledge, and understanding of the Injured Party (IP) at the 'moment-of-choice'.

Complete knowledge of the environment and actions necessary to resolve a situation are the result of well-rehearsed practices that result from the acquisition of knowledge and assimilation through training. When applying skill-based behaviour, the more knowledgeable and practiced decision makers are, they become subject to less cognitive demand, but this study revealed skill-based errors to be in the majority. Understanding the environmental cues that influence the 'moment-of-choice', the possession of knowledge that arrives at an optimum course of action, the skills to apply, and choice of process and equipment which are all dependent on experience(s), also represent components of competence.

The IPs captured by this study are required to demonstrate competence in their role and they are only considered to be competent when they have demonstrated those abilities to a suitably acceptable standard. A national suite of core operational skills and corresponding requisite knowledge sets the standard against which both the initial acquisition and ongoing maintenance of effective performance of competence is measured (NOS 2021). A general practice adopted by FRSs is for newly appointed firefighters who have not yet proved competence to be identified by an insignia displayed on their fire helmet. This leads to the assumption of skill, knowledge, and competence of those entering the hazardous environments of the emergency response domain who do not display such insignia.

Influenced by the participating FRSs the measure of the initial acquisition of competence used in the analysis focussed on five years-service. This established the assertion that skill-based errors are more likely to be the cause of injury to IPs with less than five years-service. The analysis revealed that the experience of IPs far exceeded the five-year competence threshold. Based on length of service being used as a measure of experience, skill-based errors are more likely to influence the 'moment-of-choice' of firefighters with 14 years-service and corresponding experience.

There is growing concern for the effect of 'skill fade' on judgement and decision-making performance (Lamb, et al 2014). In recent years the total number of incidents occurring from which experience can be gained and enhanced has greatly reduced. Fires have reduced by almost 56% and the number of non-fire incidents by almost 26%.

The provision of training is significant to arrangements for the establishment of knowledge, skill and understanding and the maintenance of competence. This study only focused on injuries reported to have occurred in the operational domain, injuries reported to have occurred during training were intentionally excluded. However, it should be noted that in the year of this study despite the training environment being risk assessed and supervised and include control measures designed to ensure a ‘fail safe’ environment, there were 980 reported injuries occurring in the training domain, 23 of which were major injuries (Home Office 2021).

Where the maintenance of competence is concerned, supervisors and managers are required to be competent to prepare, deliver, oversee, and assess individual performance and effectiveness of both practical and theoretical training. Analysis of AEDs in this sample and the number of injuries reported to have occurred during training would substantiate the existence and influence of skill fade affecting the ‘moment-of-choice’. It would also bring FRS arrangements for the maintenance of competence sharply into focus and worthy of closer scrutiny by both academics and practitioners.

Competence represents an individual level of expertise which is directly linked to the ability to perceive and understand features of the environment (Landy, 2018). Sensemaking requires an understanding of environmental factors, but environmental factors can themselves influence sensemaking. This is likely to occur when vision is impaired when firefighters are working in SCBA where, when firefighting in building compartments the added dimension of heat can also be influential, added to which the contextual cue of ‘persons reported’ can also influence risk taking behaviours.

Sensemaking is inextricably linked to perception and whilst the number of perception errors were relatively small. In terms of severity, they were also comparable with both time loss categories of decision and skill based errors. In terms of consequence measured by severity of injury, the majority of perception errors did not result in severe injury, those that did result in an absence of more than seven days represented 20 per cent of all perception errors which were found to be more likely to occur in artificial lighting conditions. Also linking expertise with perception errors, a small number of reported injuries occurred in darkness when the ability to perceive surroundings would be severely impaired. This in turn would suggest that at the ‘moment-of-choice’ working in darkness was either a choice of the IP or imposed on the IP by other environmental or contextual circumstances such as faulty or missing equipment. After decision and skill-based errors, perception errors were the next largest group.

Representing the smallest portion of the sample, violations are defined as *“deliberate or intended deviations from safe operating procedures or rules”* (Reason 1997:72) and typical of the working environment of the unsupervised firefighter more likely to be committed by operators at the *“sharp end of activity”* (Reason 2006:29). Violations are known to not only expose those involved to higher levels of risk but also increase the potential for accident and injury and are described as the most disturbing and dangerous of error causing behaviours (Reason 1997, Keith and Frese 2008).

In terms of severity, the majority of both types of violation did not result in time loss injury but exceptional violation resulted in the more severe of injuries. By comparison with decision and skill-based errors the severity of injury resulting from violations was slightly lower in the less than seven days category but comparable with the more severe category.

Violations are variously labelled but fall broadly under three descriptions, routine, situational and exceptional. In the classification of unsafe acts Reason (1990), includes deliberate acts of damage and describes them as acts of sabotage. However, when considering deliberate acts both cause and effect are intentional and not erroneous and form part of another broader debate. For this study circumstances where choice represented habitual short-cutting or work around existing controls or requirements was treated as routine violation. Where procedural guidance and systems of work did not completely match the context of a situation, intent was treated as exceptional violation. The similarity between routine and exceptional violations is that they both represent the intention not to follow system requirements, they are a deliberate choice.

Both types of violation are influenced by complex organisational characteristics which include the acquisition of knowledge, skill and understanding derived through training. However, the motivational framework that permits routine violation exposes the socio-cultural context of the team environment in which it occurs and the role of supervisors and managers in that culture.

Examination of the normal demographic characteristics of age, length of service and role at the time of reported injury were found to be quite revealing. Analysis demonstrated that rather than the likelihood of injury diminishing with experience, the frequency of reported injury increases. With a very small number of missing cases, the injury history variable revealed that almost half of the sample had been injured on multiple occasions. As the only indicator of experience in the data set, length of service also revealed this group to be quite experienced. Additionally, based on responses from participating FRSs a competence threshold of five years-service was established and once again the length of service of IPs exceeded this.

When exploring error types against age and experience all four were found to hold equal importance. The assertion that skill-based errors were more likely to be associated with limited experience at the lower levels of the competence threshold (<5 years-service) was tested. Only 33 IPs in the role of firefighter matched this criterion, and whilst skill-based errors formed most of those cases, it was found that the distribution of AEDs also matched that of the competent sample (>5 years-service).

With firefighters making up the largest portion of IPs, that the reporting of injury diminishes with role level would be reasonable. Consistency in the frequency of reporting based on the proportion of each role sample rather than weight of numbers confirmed that reported injury is less likely to occur the higher the role level. No obvious evidence was gathered that would explain this consistency, but the continuum of consequences (Fig 4.2) alludes to the influence of 'stigma' at the near miss threshold that may not only apply when the IP has not yet reached the competence threshold but may also apply when an IP holds a more senior position.

When analysing temporal data to explore the variation of seasonal influences; shift patterns; and time of day/night injury is reported to have occurred, national fire statistics data are limited. However, a broad range of temporal data are known to all FRSs when injury is reported and could better inform analysis of the temporal preconditions. There was a wide variation in shift and duty patterns of the participating FRSs making it necessary to rationalise them to reflect two dominant duty systems. Either representing the whole-time duty system (WDS) of the 24-hour 'available to respond' fire station or the retained/on call duty system (RDS) of the 'respond when needed' fire station. With individual injury case timings being recorded exactly, for the purpose of analysis the time-of-day injury was reported to have occurred was rationalised into four hour intervals and a separate generic period based on daytime and night-time.

National statistics reports (Home Office 2019) identified that the greatest number of fires and RTCs occurred in the late afternoon/early evening period of 16:00 – 19:59, which was also reflected in this study. Establishing a link between the frequency of exposure and frequency of injury, this is also the period when the greatest number of injuries were reported. The late afternoon/early evening period includes the normal WDS change of shift rotation from day crews to night crews. It was noticeable that this was also the period when the greatest number of reported injuries were associated with exceptional violations with the majority occurring in the last hour of the period.

Whilst this level of violating behaviour resulting in injury may be coincidental, an important temporal characteristic not gathered in this study was the normal time of the change of WDS shift from day to night crews. This knowledge may reveal a socio-cultural behaviour where performance of task activities is influenced by returning home later than normal. This may also be related to the day of the week on which injury is being reported. The study found that over half of injuries were reported to have occurred in the middle of the normal working week with the majority being on Tuesday and the larger proportion resulting from decision errors.

The association between fatigue and injury was examined in two ways. Firstly, the number of injuries being reported to have occurred towards the end of full WDS tour of duty was compared with those reported at the commencement. Analysis revealed that injury was more likely to be reported on the commencing day shift of the tour and slightly less were reported to have occurred on the night shifts. That the greater number are reported on the first day shift of a tour is also worthy of closer scrutiny, in particular the relationship between an IP returning from an extended period of leave to commence a tour of duty. An extended absence of leave can be as long as 21 days which could in turn have a short term effect on knowledge/skill degradation and act as another temporal precondition of accident causation.

The second examination for the influence of fatigue considered seasonal variation on call demand and any corresponding increase in reported injury. It was found that this was the case with almost twice as many injuries being reported in July. A relatively dry spring and summer period resulted in an increase of fires of various size involving grassland, woodland, and crops. This is where firefighting conditions are often physically demanding where the addition of heat and humidity can lead to fatigue and dehydration both of which are known to influence judgement and decision-making. This was also further evidence of the relationship between frequency of exposure to the hazards of the emergency response domain with reported injury and the influence of environmental preconditions.

Providing valid data relating to environmental preconditions proved to be unpopular with the participating FRS managers. Despite which, no investigation of slips, trips, and falls would be complete without knowledge of surface and ground conditions the significance of which is directly proportional to severity of injury. The limited data that was provided relating to surface, ground and weather conditions was only used to contribute to general discussion of the relationship between environmental preconditions and reported injury.

The ground conditions typical of summer grassland firefighting are difficult underfoot, physically demanding, and likely to result in sprains and strains normally associated with slips, trips, and falls. That a little over a third of the indicative sample identified the IP was working on uneven, overgrown, steep, or sloping surfaces is further evidence of a relationship between seasonal influences and reported injury. This relationship is further substantiated by the second largest sample in the analysis which confirmed that the weather conditions were hot, dry, and warm in the vast majority of cases and whilst all AEDs were represented, skill-based and perception errors accounted for a large proportion.

Also noticeable were the number of errors resulting from violation occurring in hot weather, the majority being associated with exceptional violations. Incidents involving grass and heathland are more likely to occur in rural areas and for the attending resources, they may also result in uncommon travel distances. The propensity for violation in such circumstances could add weight to the earlier inference of an association with socio-cultural behaviours influenced by prolonged attendance at an incident beyond the normal conclusion of a WDS day shift.

Of the four environmental preconditions, visibility provided the more representative analytical sample and revealed that the vast proportion of reported injuries occurred during normal daylight conditions when the surface on which the IP was working was dry and flat. As lighting conditions diminish resulting in the need for increased dependence on artificial lighting, the number of reported injuries increased. Further supporting the argument for the effect of visual impairment on perception, the majority of reported injury resulting from perception errors occurred in artificial lighting conditions.

Of all the AEDs associated with the use of torchlight, perception errors represented the largest number. Whilst injury may have occurred whilst the IP was indoors in a fire compartment working in darkness or smoke and wearing SCBA during firefighting or search and rescue operations, only two reported injuries occurred in such conditions.   However, given the number of cases where information was not provided by FRSs this is likely to be a greater number, one which could better inform the contextual preconditions at the ‘moment-of-choice’.

Based on the type of incident being attended, whether it includes the heat and smoke of the confines of an industrial or commercial building fire or domestic property, or in rapid flowing flood water, contextual preconditions have a direct influence on the cognitive demand placed on a decision maker. Along with environmental preconditions they are the ‘what, so what, and what next?’ (Golightly et al 2010), of the three levels of situation awareness. The emotive addition of ‘persons reported’ to the decision-making context increases that demand and is most representative of the critical decision activity of the ‘moment-of-choice’. The sample on which the analysis of contextual preconditions is based clearly demonstrates that it is strongly influenced by the frequency of exposure to the hazardous context of fires and firefighting as opposed to the variety of non-fire incidents FRSs are called upon to attend.

Of quite some concern is the number of reported injuries that regardless of incident type occur in the response phase of an incident before IPs attend the incident location. Whilst a proportion of them were likely to involve RTCs involving responding appliances and vehicles, the response phase of an incident includes the movement of WDS IPs from various locations within the precincts of a fire station to mount the responding appliance(s).

In the case of the RDS or On-call responder, it also includes the journey from their home or work location to the fire station where their appliance(s) are located. In the year of this study an RDS firefighter sustained fatal injuries when involved in an RTC whilst undertaking just such a journey. Senior officers who also respond from home overnight are also exposed to similar responding hazards.

Analysis revealed all five AEDs were associated with contextual preconditions and whilst decision and skill-based errors continued to dominate, errors of perception and violation regularly associated with driving error accounted for 45 per cent of reported injuries. The exact activity of IPs reporting injury in the response phase was not separately requested during data capture with the participating FRSs. Analysis was instead determined by the number of data that listed multiple IPs with the same or immediately sequential case numbers in the response domain. The emotive contextual precondition of 'persons reported' was also not sought, this was instead assumed to be captured by the 'critical activity' variable discussed below.

Once in attendance at an incident location the process of alighting appliances, removing equipment, assembling, and preparing it for use resulted in the second largest number of reported injuries. Haste resulting from the 'persons reported' cue may also have had some influence on behaviours in the attendance domain. On this occasion, linked to the use and handling of equipment, skill-based errors accounted for the largest single error type. With the next largest error type being decision errors, which may also be associated with selection and use of equipment and raises the question of plurality of AEDs. However, the existence and influence of active error plurality signposts the importance of reliability in the judgements of the participating SMEs which is the focus of Study 2 (Chapter 5).

The 'persons reported' cue is an important factor of the critical activity variable where those involved in tasking decisions and task activity accept a high level of risk. This is first made implicit by National Operational Guidance (NOG) which in decision making guidance directed at task allocation sets an expectation that when life is at risk "*a higher risk to firefighters may be accepted"* (NOG 2021g). Further influencing contextual preconditions and no longer using the auxiliary 'may' NOG extends the boundary of behavioral expectation with what is described as the Firefighters Safety Maxim:

> *"At every incident the greater the potential benefit of fire and rescue actions, the greater the risk that is accepted by commanders and firefighters. Activities that present a high risk to safety are limited to those that have the potential to save life or to prevent rapid and significant escalation of the incident."*
>
> National Operational Guidance (2021g)

It is this extension of the maxim beyond life safety to include other specific 'activities' that influences the definition of the critical activity AED. Acting as an implicit behavioral cue and cognitive influence the maxim also adds to contextual preconditions. To examine the potential influence of such cues on reported injury associated with a critical activity Study 3 was designed to interview a sample of the 93 cases identified by the SMEs of the participating FRSs in this study.

The final injury activity of the contextual preconditions category captured injuries reported to have occurred in the concluding phases of task activity when regardless of incident type, hazards and risks have diminished. In the year of the study this also included injuries reported to have occurred during the return journey to a turn-out location unless mobilised during the journey in which case the responding category would once again apply. Only 33 cases of the sample were captured in this category and exceptional violation was the only AED not to influence the 'moment-of-choice' of an IP.

Cultural influences on reporting of injury were not originally scrutinised in the literature review they were instead explored to expand on the rationale for setting aside gender difference in this study. However, the existence of an under-reporting culture amongst female firefighters emerged in the literature and is labelled as ‘stigma’ related. A similar reporting stigma may also influence the reporting of minor injury amongst supervisors and managers. It is this assertion that influences the expression ‘reported injury’ used throughout this thesis. Evidence of a socio-cultural influence also emerged from the frequency and AEDs associated with reported injury proximal to the change of shift.

Several issues emerging from this first study identify limitations of the research worthy of further scientific scrutiny. Amongst them, plurality in the application of AEDs draws attention to the definition and classification of unsafe acts and their reliability as an analytical tool which is partially addressed in the test of a Human Factors analysis in the following study (Chapter 5). Skill fade, the influence of culture and the plurality of AEDs are further considered in the general discussion of Chapter 7.

In conclusion, the analysis of AEDs in this sample and the number of injuries reported to have occurred during training would substantiate the existence and influence of skill fade affecting the ‘moment-of-choice’. It would also bring the relationship between reported operational injury and arrangements for the maintenance of competence sharply into focus and worthy of closer scrutiny.

5. Study 2 HUMAN FACTORS ANALYSIS (RQ3).

5.1 Introduction.

In Study 1 of the previous chapter, Reason's classification of unsafe acts (Reason 1990), was used to establish a taxonomy of active error descriptors (AEDs) which relate to decision-based; skill-based; or perception-based error; or violations. These AEDs were used as a predictor variable in a descriptive analysis to explore a broad range of safety data relating to the demographic; temporal; environmental and contextual characteristics present at the time of an injury causing accident. The primary area of interest was the errors and violations that can be associated with the outcome of an unsafe act resulting in a reported injury occurring in the emergency response domain of the FRS.

It was found that the greatest number of reported injuries involved either a decision-based or skill-based error. A relatively small number involved either routine or exceptional violations occurring in critical situations, which in turn also exposed the role and influence of supervisors and managers. A small proportion of reported injury was attributable to perception errors which it was argued may be associated with working in Self Contained Breathing Apparatus (SCBA) when firefighters are more likely to be remote from the controlling influence and oversight of their supervisors and working in the stressful conditions of heat and smoke. In terms of severity of injury, both decision-errors and skill-based errors were the dominant cause of time loss. However, the majority of the more severe injuries were the result of skill-based errors. These were more likely to involve the 'moment-of-choice' of firefighters who were deemed by their supervisors and managers to be competent.

Using two case studies, this second study explored the application of an analysis tool designed to effectively investigate the human factors of accident causation. A framework known as the Human Factors Analysis and Classification System (HFACS) (Weigmann and Shappell, 2003) is used to explore the judgements of a sample of the FRS managers participating in Study 1.

Opportunity is also taken to examine the applicability of the HFACS to the emergency response domain of the FRS and measure the reliability that can be placed in the categories used in coding a modified FRS sector specific variant of the HFACS.

As described in the methodology of Chapter 3 above, the HFACS was chosen as the diagnostic tool for this study for its compatibility with the cognitive performance classifications of the Generic Error Modelling System (GEMS) (Reason 1990). This is also the model on which 'error typing' using the Active Error Descriptors (AEDs) of Study 1 are established (Reason 1990) and serves to tri-angulate their use. In turn, the structure of the HFACS taxonomy itself is derived from the defensive barriers described by Reason in his Swiss Cheese Model (SCM) (Reason 1997).

The HFACS Framework comprises of four main levels of failure, each corresponding to the defensive organisational barriers depicted by the SCM (Reason 1997), (Figure 2.3 page 52). Identified as Unsafe Acts, the first HFACS level captures the AEDs of Study 1 and examines their effect on accident causation. Here, they represent the active failures of the accident causing sequence of the SCM. The second level of the HFACS examines the environmental and contextual pre-conditions of accident causation and the next level captures the influence of unsafe supervision. Together, unsafe supervision and the fourth level of failure, organisational influences, represent the latent conditions of the SCM sequence (Figure 5.1 below).

Each of these main levels of failure is comprised of several causal categories and as can be seen in Figure 5.1 some, in turn, have a number of sub-categories against which coding selections are made. However, early studies of the HFACS taxonomy argued that these original causal categories and their sub-categories lack specificity (Beaubien and Baker, 2002). As an example, the preconditions for unsafe acts causal category of Personnel Factors includes a sub-category for 'Crew Resource Management' (CRM). CRM relates to behaviours associated not only with individuals but also within groups such as teamwork, communication, and decision-making (Kanki, Anca, and Chidester, 2019). Consequently, it has been argued that simply using a generic category label such as CRM which has many components, without closer scrutiny of each and the causal concepts to which they relate restricts the opportunity for understanding, targeted intervention, and injury reduction strategies.

An example of an early adaptation of the HFACS taxonomy that includes this additional layer of specificity was developed by the US Department of Defense (DoD, 2005). In the development stage of the DoD HFACS variant several of the original causal sub-categories were re-labelled and supplemented with the addition of 149 specific identifiers described as nanocode statements. In some cases, as many as 16 of these statements were added to a single causal sub-category. However, this added layer of granularity introduced by the use of nanocodes has raised concerns about the efficacy of reliability in the results of analyses of sector specific variants of the original HFACS taxonomy which is further discussed below.

Since the development of DoD HFACS in 2005, also adding additional granularity many sector specific variants (see Table 3.1 p108) have taken the same approach. A similar approach is taken in this study where a suite of nanocode statements emerged from a two stage process of moderation.

5.2 Moderation of the HFACS Taxonomy.

The process of moderation was designed to examine the usability of the HFACS guidance and is based entirely on Weigmann and Shappell's original taxonomy as published in 2003. However, in addition to the four levels of failure and their corresponding causal categories, when describing each level of the HFACS taxonomy Weigmann and Shappell use a number of descriptors which they describe as 'selected examples' of causation. Although not specifically

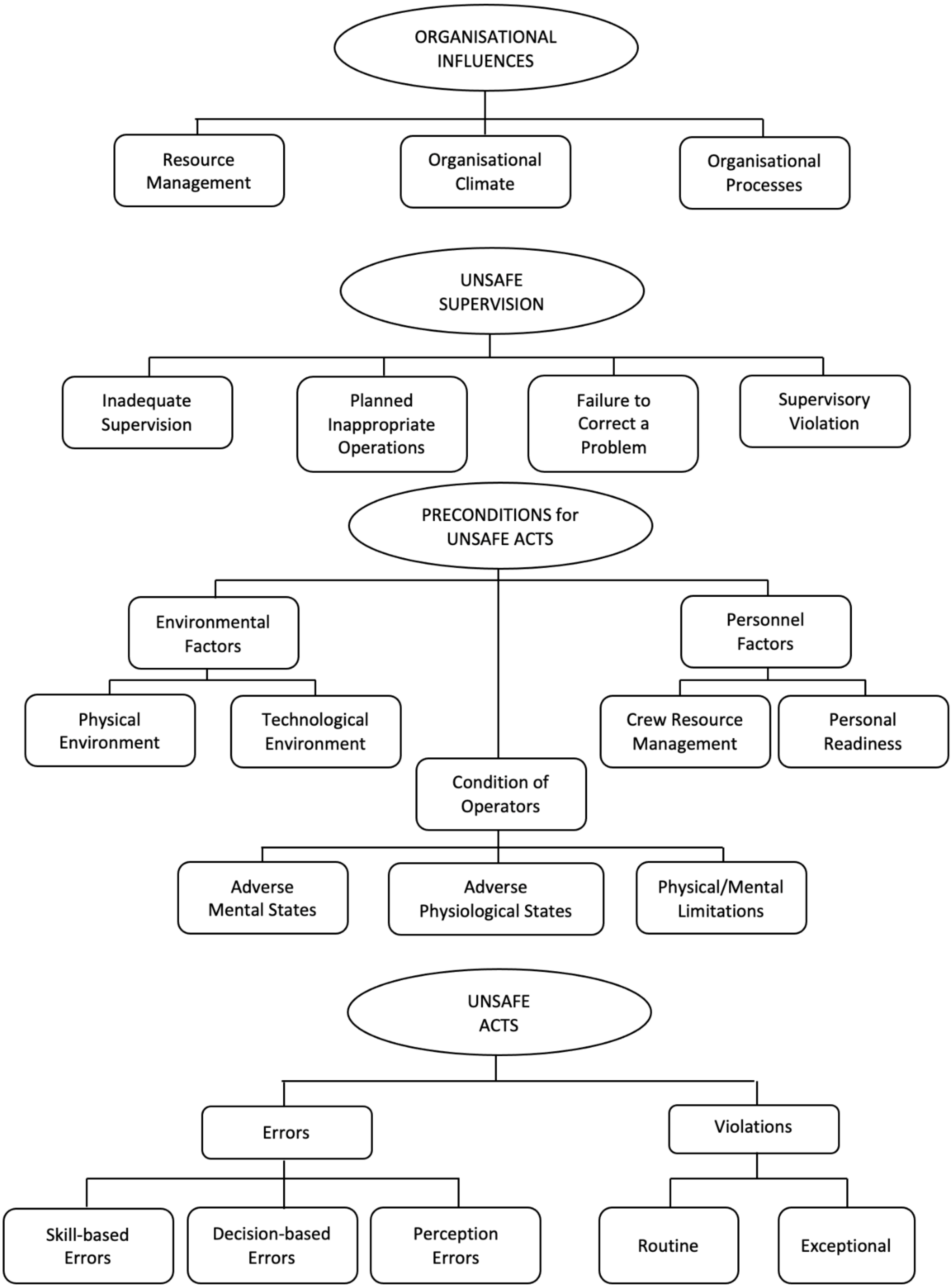


Figure 5.1 Demonstrating the four levels of failure of the original Human factors Analysis and Classification System and their supporting causal categories. Adapted from Weigmann & Shappell (2003).

labelled as identifiers or nanocodes they are used by the authors in support of their narrative describing the causal categories. It is worthy of note that in each case the authors also emphasise that those ‘selected examples’ that are used should not be treated as a complete list, inferring that several more were used in their studies (Weigmann and Shappell, 2003).

These ‘selected examples’ of causation were initially treated as representative nanocodes for the purpose of constructing the draft guidance for beta testing. However, several of the original selected examples mainly those applicable to the unsafe acts and some to the preconditions of unsafe acts levels of failure were explicit to aviation and as an initial stage of moderation, excluded from the taxonomy exposed to beta testing (Table 5.1 below).

Beta testing was conducted by two subject matter experts (SMEs) with similar professional status, levels of experience, and roles as the selected managers participating as coders as described in the Methodology of Chapter 3 above (page 109). At the conclusion, each raised concern about the applicability and need for interpretation of the remaining initial nanocode statements and some of the labels applied to the causal categories. In response, they were asked to identify a) those that were not easily interpreted to the FRS domain; b) those that could be applied with minor amendment; and c) sector specific statements that should be added that would be suitable to each of the causal categories.

Amendment at this stage also included observations relating to the naming of causal categories. At the level of unsafe supervision, the first three causal categories were amended to better reflect the role of the FRS supervisor/manager whether performing an incident command role or during routine management of non-operational activities. The first of these, Inadequate Supervision was amended to Preparation for Operations largely to include the supervisory responsibility for ensuring the competence and capabilities of firefighters in all aspects of their role.

Table 5.1 Indicating selected example statements of the original HFACS taxonomy explicit to aviation and excluded from Beta Testing.

Failure Level	Causal Category	Excluded Explicit Selected Examples
Unsafe Acts	Skill Based Errors	Breakdown in visual scan
		Over controlled the aircraft
		Omitted checklist item
		Over reliance on automation
	Routine Violations	Inadequate briefing for flight
		Failed to use ATC radar
		Flew an unauthorised approach
		Filed VFR in marginal weather
		Failed to inspect aircraft after in-flight caution light
	Exceptional Violations	Performed unauthorised acrobatic manoeuvre
		Improper take-off technique
		Failed to obtain valid weather brief
		Exceeded limits of aircraft
		Failed to complete performance computations for flight
		Not current/qualified for flight
		Unauthorised low-altitude canyon running
Preconditions for Unsafe Acts	Environmental Factors	Altitude
		Vibration
		Toxins in cockpit
		Checklist layout
		Display/interface characteristics
		Automation
	Adverse Mental States	Poor flight vigilance
		Alertness (drowsinness)
		Circadian dysrhythmia
	Adverse Physiological States	Hypoxia
		Intoxication
		Motion sickness
		Effects of OTC medications

The Planned Inappropriate Operations label was amended to Supervision of Operations to specifically capture the role of a FRS supervisor during incident operations, and the Failure to Correct a Problem label was changed to Managing Safety Issues which better reflected the generic responsibility of FRS supervisors/managers for the health, safety, and welfare of others. In addition, the beta testers suggested that at the level of Preconditions for Unsafe Acts the causal categories should be re-named to simplify their meaning to environmental, team and individual factors.

The beta testers also recommended that at the Preconditions for Unsafe Acts level the sub-categories of Adverse Physiological States and Physical/Mental Limitations should be combined into a single category. At the Organisational Influences level both testers were of the opinion that coders would not normally be sighted on many of the causal sub-categories and suggested it either be excluded from the study or the sub-category labels be simplified or combined. Consequently, for Case Study 1 (CS1) the Resource Management sub-categories were simplified and in the Organisational Climate category the sub-categories of culture and policies were combined.

Table 5.2 summarises the results of the initial and subsequent beta moderation where the 140 original ‘selected examples’ offered by Weigmann and Shappell (2003) were initially amended to 117 nanocode statements. Appendix 5 details the sequence of adjustments made to create nanocode statements and amended category labelling.

In addition to the guidance for making the AED judgements used in Study 1; basic guidance on the use of the HFACS taxonomy; and condensed case study documents described in Chapter 3, coders were provided with an Excel workbook containing four separate worksheets for coding each of the four main levels of failure and their causal categories. In each case, based on their interpretation of the condensed case study documents, simple guidance (Appendix 7) directed coders to identify those nanocode statements they believed to have had some influence on the outcomes of each case study event at each level of failure.

Table 5.2 Summarising the results of moderation of the 140 original selected examples of causation offered by Weigmann and Shappell for application as nanocode statements used in Case Study 1.

Failure Level	Initial count of Selected Examples	Case Study 1			Final count of nanocodes
		Removed	Revised	Added	
Unsafe Acts	35	16	15	3	22
Preconditions for Unsafe Acts	47	22	16	19	44
Unsafe Supervision	27	13	11	4	18
Organisational Influences	31	7	21	9	33
Totals	140	58	63	35	117

No restriction was placed on the frequency of selection of an individual nanocode statement, or the number of statements coders considered to be influential. This would also allow additional analysis based on the percentage of agreement between coders as detailed in the analysis below. At the conclusion of CS1, coders were asked to comment on the moderation criteria applied in beta testing relating to difficulty of interpretation; need for minor amendment; and addition of sector specific statements. Due to the lack of detail in the case study narrative, the coders all expressed difficulty in applying the high level of failure relating to organisational influences. Consequently, this level was excluded from Case Study 2 (CS2).

Following CS1, further moderation of the Unsafe Acts level of failure largely related to individual behaviours. At this stage the phraseology of the individual responsibilities of the FRS Safe Person Principles (DCLG 2013) were introduced. Discussed in the FRS error management context of the literature review of Chapter 2 above (see section 2.8), the five individual responsibilities to being a safe person, describe expected behaviours required of individuals during incident activities and include being competent to perform a task; self-awareness; being observant and situationally aware; decisive when dealing with hazards and risks; and to communicate unexpected developments to team members, supervisors and commanders (DCLG 2013).

Several statements that would expose failure in some of these areas were added to the error category of the Unsafe Acts level of failure of CS2. Based on the FRS Safe Person Principles (DCLG 2013), the sub-category of Skill-based errors included a failure to communicate safety critical information and unexpected developments as well as failure to recognise physical limitations to perform the task in hand. Addition to the Perception Error sub-category included failure to ensure the necessary information to perform safely, ensure vigilance for personal and team safety and react safely to unexpected hazards. The Decision Error sub-category included inadequate risk assessment where an individual failed to take action to reduce personal and team exposure to risk. Failure to recognise personal limitations in knowledge to carry out a task was also added to the Decision Errors sub-category.

Two additions were also made to the Pre-conditions of unsafe acts level of failure where an individual's failure to ensure competence to perform an allocated task and to work sensibly and responsibly within the command and control arrangements of an incident were added to the personal readiness causal sub-category.

Table 5.3 summarises the results of the coder moderation stage where, excluding the Organisational Influences failure level of the HFACS taxonomy, the 84 nanocodes applied to the first three levels of failure of CS1 were amended to the 103 nanocode statements applied to the first three levels of failure of CS2 (Appendix 7). Excel workbooks used for CS2 were then amended to capture this stage of moderation and applied to the analysis described below.

Table 5.3 Summarising the results of nanocode amendment following Case Study 1 excluding the Organisational Influences level.

Failure Level	Nanocodes Applied to Case Study 1	Case Study 2			Final count of nanocodes
		Removed	Revised	Added	
Unsafe Acts	22	2	20	11	31
Preconditions for Unsafe Acts	44	6	36	14	52
Unsafe Supervision	18	2	13	4	20
Totals	84	10	69	29	103

5.3 Study 2 Analysis.

Inter coder reliability or more precisely inter coder agreement is used to check the reliability of categorisation and inferences drawn from varying types of data analysis. The higher the extent of inter coder agreement the easier it is to trust coded data as reliable, trustworthy, and exchangeable (Hayes, 2005; Lombard, Snyder-Dutch, and Bracken, 2002). Several measures can be used for testing inter coder reliability, but few also measure the level of agreement, which is important to Study 2 where, without specific training in the use of HFACS, seven independent coders were using the HFACS taxonomy for the first time.

Krippendorff's Alpha (Kα) is a diagnostic measure that independently tests the degree or extent of agreement between coders evaluating given units of categorisation. Kα universally applies to any number of coders or observers across any number of measures, scales or categories and any level or scale of measurement including nominal, dichotomous, ordinal, interval, and ratio. It also applies to a dataset with missing or incomplete data points across both small and large samples (Hayes and Krippendorff, 2007).

Krippendorff argues that reproducibility is the single most important test to check the validity of research findings (Krippendorff, 2004). Reproducibility implies that the coding instrument carrying the same set of instructions for different observers studying the same phenomenon produces similar to comparable results within an acceptable margin of error, which makes it particularly relevant to the aims of Study 2 where human error classification is being introduced to Fire Service coders for the first time, and a suite of sector specific nanocode statements are also being developed and examined. Consequently, this analysis was initially conducted using $K\alpha$ and applied to each level of failure, causal category, and where applicable causal sub-category of HFACS depicted by the coders' selection of the relevant supporting nanocode statements (see tables 5.4 and 5.5 below).

However, based on the premise that percentage agreement should be *"…considered the industry standard measure for agreement for safety data…"* (Olsen and Shorrock, 2010: 440), as explained in the general discussion of Chapter 7, percentage agreement was also applied to the results of this study and used as a comparator with the $K\alpha$ results (Table 5.6 below).

5.4 Study 2 Results.

In this section the data coded by seven coders using a dichotomous measure as explained above observes the standard principle of interpretation, the value of $K\alpha$ ranges from '0' to '1' where '0' indicates random categorisation and '1' indicates perfect reliability (Krippendorff, 2011). A $K\alpha$ value of 0.80 is generally considered as indicating a good level of reliability in agreement between coders of $K\alpha$ 0.67 to $K\alpha$ 0.60 represents an acceptable level. Any value lower than 0.60 represents low reliability (De Swert, 2012). In contrast, the percentage agreement analysis is based on a threshold of 70% representing an acceptable minimum as applied by Olsen and Shorrock in their sector specific study (Olsen and Shorrock, 2010).

Amongst the information provided for the data capture exercise of Study 1, participants were asked to identify the accident investigation model they had been trained to use and considered themselves to be conversant with. Of the seven participants it was noted that three were using the Events and Conditional Factors Analysis model (ECFA) (Kingston and Koorneeff, 2014), the remaining four coders were all using completely different models. In order to detect any potential consistency in the judgements of coders using the ECFA model, the causal category analyses are reported as three results: P2.1 for all coders; P2.2 for coders using the ECFA model; and P2.3 for the remaining four coders.

5.4.1 Case Study 1.

Across the first main failure level of Unsafe Acts the level of agreement is very low ($K\alpha$ = 0.23) but does nevertheless demonstrate a moderate level of agreement for the presence of decision errors in the influence of unsafe acts ($K\alpha$ = 0.46). In the causal category of violations, the group of coders using entirely separate accident investigation models had a stronger level of agreement than the ECFA group. More so, in the presence of routine violation in unsafe acts.

Where the second HFACS failure level of Preconditions of Unsafe Acts is concerned there is almost a complete absence of agreement ($K\alpha$ = 0.10). Coders using the ECFA model of accident investigation demonstrate a stronger level of agreement that the presence of individual factors largely relating to the physical/mental limitations of those involved, existed as preconditions leading to unsafe acts. In a similar way the ECFA coders demonstrated a stronger level of agreement that unsafe supervision was exposed in the way supervisors/managers were managing safety ($K\alpha$ = 0.37).

Although coders stated they experienced some difficulty in interpreting the higher HFACS failure level of Organisational Influences, and the level of agreement is generally unreliable, three selections of the causal sub-category demonstrate perfect reliability in agreement amongst the ECFA coders ($K\alpha = 1.0$). The ECFA coders independently agreed that the influence of financial resource management, the culture and policies of the organisation and the organisation of operations were influential in the outcome of CS1. In each case, there was a complete absence of agreement amongst the separate group of coders which influenced the overall result ($K\alpha = 0.00$).

The overall percentage agreement comparison at the HFACS causal category levels similarly reflected the low $K\alpha$ results (35%). At the causal sub-category level percentage agreement improved (49%). The ECFA group demonstrated a highly reliable percentage of agreement at the causal category level (93%) and a reliable level of agreement at the causal sub-category level (72%). With slight differences, this was also true of the separate group of coders (83%, 75%) (see Table 5.6 below).

5.4.2 Case Study 2.

Based on the review comments of coders following CS1, the HFACS failure level of Organisational Influences, comprising 30 nanocode statements, was excluded from CS2. Several of the nanocode statements of the remaining three categories were amended and as described above, 18 new sector specific statements were added.

The overall level of agreement for the existence of Unsafe Acts remained unchanged from CS1 ($K\alpha = 0.23$). With an increase in the number of nanocode statements, in keeping with the Olsen and Shorrock (2010) assertion that increased choice reduces reliability, the level of agreement between coders weakened significantly at both causal category levels of errors. However, as with CS1, the strongest level of agreement lay in the presence of decision errors having had some influence on the occurrence of unsafe acts.

Table 5.4 Level of agreement using Krippendorff's Alpha for Case Study 1.

HFACS Level of Failure	Causal Category	Krippendorff's Alpha P2.1 All Coders	Krippendorff's Alpha P2.2 ECFA Coders	Krippendorff's Alpha P2.3 Separate Coders	Causal Sub-Category	Krippendorff's Alpha P2.1 All Coders	Krippendorff's Alpha P2.2 ECFA Coders	Krippendorff's Alpha P2.3 Separate Coders
Unsafe Acts 0.23	Errors	0.26	0.14	0.30	Skill Based	0.1	0.10	0.19
					Perception	0.00	0.00	0.00
					Decision	0.46	0.44	0.37
	Violations	0.08	0.00	0.34	Routine	0.14	0.00	0.45
					Exceptional	0.00	0.00	0.00
Preconditions of Unsafe Acts 0.10	Environmental Factors	0.16	0.28	0.19	Physical	0.16	0.28	0.19
					Technological	0.12	0.00	0.18
	Team Factors	0.15	0.21	0.00	Crew Resource Management	0.05	0.16	0.00
					Personal Readiness	0.04	0.00	0.00
	Individual Factors	0.15	0.35	0.00	Adverse Mental State	0.00	0.28	0.00
					Physical Ability	0.37	0.42	0.23
Unsafe Supervision 0.18		0.18	0.23	0.05	Preparation for Operations	0.00	0.00	0.00
					Supervision of Operations	0.13	0.00	0.10
					Managing Safety	0.21	0.37	0.06
					Supervisory Violation	0.00	0.00	0.00
Organisational Influences 0.14	Resource Management	0.28	0.27	0.24	Human	0.32	0.43	0.27
					Financial	0.00	1.00	0.00
					Equipment/Facilities	0.15	0.00	0.27
	Organisational Climate	0.02	0.00	0.00	Structure	0.00	0.00	0.00
					Culture and Policies	0.00	1.00	0.00
	Organisational Processes	0.09	0.19	0.07	Operations	0.00	1.00	0.00
					Procedures	0.04	0.11	0.08
					Oversight	0.02	0.26	0.00

However, the change in nanocode statements relating to the effect of violations on unsafe acts demonstrates a much improved level of agreement ($K\alpha$ = 0.08 - 0.28). At the causal sub-category level, for the ECFA coders there is a highly reliable level of agreement that unsafe acts arising from situational violations were present in CS2 ($K\alpha$ = 1.0).

In the HFACS failure level of Preconditions of Unsafe Acts, reliability in the overall level of agreement is stronger than in CS1 ($K\alpha$ = 0.10 - 0.23). At the first sub level this was also the case for environmental ($K\alpha$ = 0.16 - 0.31), and team factors ($K\alpha$ = 0.15 - 0.34). The strengthening of agreement is also consistent at the second subcategory level where agreement in the presence of physical ($K\alpha$ = 0.16 - 0.34) and technical factors ($K\alpha$ = 0.12 - 0.27) also improved and agreement amongst the ECFA group was significantly stronger than in CS1 ($K\alpha$ = <0.00 - 0.55).

Supporting the Olsen and Shorrock (2010) argument for reduced consensus in sector specific variants, the overall percentage agreement comparison of the six main HFACS categories did not reflect the slight improvement of $K\alpha$ results and was slightly lower than that of CS1 (32%). At the causal sub-category level there was a slight improvement in the overall percentage agreement (49% - 53%) (Table 5.5 below).

Table 5.5 Level of agreement using Krippendorff's Alpha for Case Study 2 (excluding the Organisational Influences category).

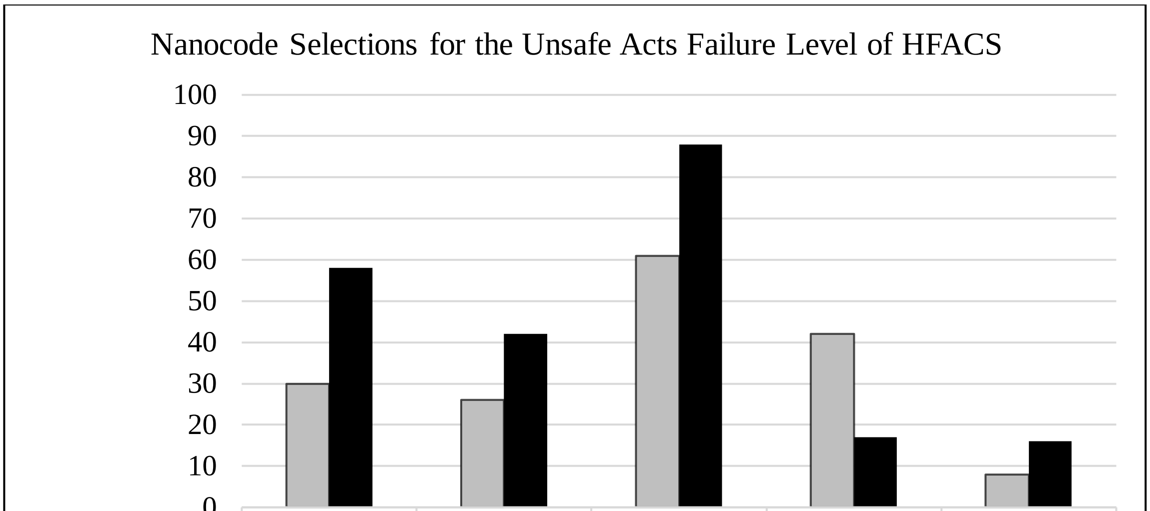
HFACS Level of Failure	Causal Category	Krippendorff's Alpha P2.1 All Coders	Krippendorff's Alpha P2.2 ECFA Coders	Krippendorff's Alpha P2.3 Separate Coders	Causal Sub-Category	Krippendorff's Alpha P2.1 All Coders	Krippendorff's Alpha P2.2 ECFA Coders	Krippendorff's Alpha P2.3 Separate Coders
Unsafe Acts 0.23	Errors	0.19	0.12	0.15	Skill Based	0.00	0.00	0.00
					Perception	0.09	0.04	0.08
					Decision	0.47	0.39	0.40
	Violations	0.28	0.27	0.44	Routine	0.28	0.27	0.44
					Situational	0.73	1.00	0.53
Preconditions of Unsafe Acts 0.23	Environmental Factors	0.31	0.41	0.19	Physical	0.34	0.31	0.33
					Technological	0.27	0.55	0.00
	Team Factors	0.34	0.50	0.18	Crew Resource Management	0.28	0.36	0.17
					Personal Readiness	0.02	0.00	0.00
	Individual Factors	0.00	0.15	-0.05	Adverse Mental State	0.00	0.10	0.00
					Physical Ability	0.01	0.11	0.00
Unsafe Supervision 0.28		0.21	0.33	0.17	Preparation for Operations	0.07	0.04	0.00
					Supervision of Operations	0.27	0.39	0.00
					Managing Safety	0.00	0.18	0.21
					Supervisory Violation	0.00	0.00	0.00

Table 5.6 *Percentage agreement across both case studies for three coding groups (excluding the organisational influences category).*

HFACS Level of Analysis	Percentage Agreement					
	Case Study 1			Case Study 2		
	All Coders	ECFA Coders	Separate Coders	All Coders	ECFA Coders	Separate Coders
Main and First Subcategory	35	93	83	32	100	83
Nanocodes	49	72	75	53	77	77

Whilst the percentage agreement between the separate group of coders was acceptable and remained constant at the causal category levels (83%), the ECFA coders demonstrated total agreement (100%). At the causal sub-category level both groups demonstrated a similar and reliable level of agreement (77%).

The analysis of coder selections was conducted as a dichotomous choice based on the presence or otherwise of a characteristic depicted by a relevant nanocode statement. As previously stated, the primary area of interest of this research relates to the errors and violations that can be associated with the erroneous outcome of an unsafe act. As a comparator with the selection of AED's in Study1, coders were asked to record the frequency of their individual nanocode selections in all categories. It was found that in keeping with the descriptive data analysis of Study 1, skill-based and decision-based errors were dominant choices in both case studies, more so in CS2 (Figure 5.2 below). CS1 reveals a higher level of evidence of the presence of routine violations.



	Skill Based Errors	Perception Error	Decision Error	Routine Vioilations	Exceptional Violations
Case Study 1	30	26	61	42	8
Case Study 2	58	42	88	17	16

Figure 5.2 Demonstrating the dominance of coder selections for the influence of errors in the outcomes of both case study events.

At the next HFACS failure level relating to the Preconditions of Unsafe Acts, a specific difference in the two case studies emerged. It was found that nanocode selection of CS2 relating to the physiological state of several of the actors involved was influenced by evidence of fatigue described in the narrative of the respective reports and their sequential timed event plots (Appendices 3 and 4) which also represents aspects of crew resource management (Kanki, Anca and Chidester, 2019). This too, influenced nanocode selections at the next HFACS failure level of Unsafe Supervision where coders associated the decision making errors of the first HFACS failure level (Unsafe Acts) and physiological state of the second failure level (Preconditions of Unsafe Acts) with poor supervision. Although with a lower frequency of selection, this was also reflected in CS1. Collectively, this would identify a central theme where the influence of supervision linked to decision-based errors played a dominant role in the outcomes of both case study events.

5.5 Study 2 Application of a Human Factors Analysis Tool – Summary.

This study had two objectives firstly, to explore the extent to which the judgement and agreements of a sample of the FRS managers participating in Study 1 could be considered reliable when using a specific Human Factors (HF) Analysis Tool. The second is to examine the applicability of the chosen tool to the emergency response domain of the FRS when modified to a more sector specific variant an overview of which is provided in Table 5.7 below. As described in Chapter 3, the Human Factors Analysis and Classification System (HFACS), (Weigmann and Shappell 2003) was the chosen HF analysis tool.

Table 5.7 Providing an overview of Study 2.

Research Question(s)	Overview	Participation
RQ3	Uses the concept of 'error typing' developed in Study 1. Participants identify Active Error Descriptors (AEDs) using two open source case study events. Participants use the Human Factors Analysis and Classification System (HFACS) for the first time as the HF analysis tool. Examines the reliability that could be placed in the selection of various HFACS categories. Examines the applicability of HFACS to the emergency response domain of the FRS when modified to a more sector specific variant.	Two BETA testers prior to releasing the guidance materials. Seven FRS participants taken from Study 1 with previous experience of the error typing concept.

Whilst application of the HFACS tool would suggest that limited reliability should be placed in the AED judgements of Study 1, what this study does not identify is whether the limited experience gained by participants in applying HFACS judgements to CS1 was influential in any increase in reliability of judgements demonstrated by strengthening of $K\alpha$ values in CS2.

Alternatively, it is not known if it was the introduction of more sector specific nanocode statements that had an influential effect.

It is also not clear if case studies based on the similar and for the most part, less severe injury events such as those to which the AED judgements were applied in Study 1 would yield the same or stronger reliability measures. Whilst the approach taken in the provision of supporting guidance and pre-briefing information to each case study event was as similar as possible, and despite the consequences of CS1 being far more significant resulting in four fatalities as opposed to the single fatality of CS2, the circumstances 'on the ground' at the time of each event were physically different. As an example, in the case of CS2 the source reports (Fire Brigades Union 2014, 2017, Scottish FRS 2016, Warwickshire FRS 2016). describe how firefighters were being required to re-enter the heat of the burning building wearing self-contained breathing apparatus (SCBA) with little time for rest, recuperation and rehydration. Whereas, in CS1 the fatalities all involved firefighters making their initial and only entry in SCBA to locate and extinguish a fire.

It is acknowledged that the results clearly demonstrate that, based on coders dichotomous selections for the presence or otherwise of an influential factor described by the nanocode statements, the level of agreement between coders is consistently below $K\alpha$ 0.60. In the majority of cases, they demonstrate a complete absence of agreement. However, given the amendment and application of a more sector specific suite of nanocode statements for Case Study 2 (CS2), on this occasion the utility of $K\alpha$ lies in its ability to provide a measure that can identify a strengthening or weakening in the level of agreement between the two case studies across all levels of failure of the HFACS taxonomy.

When the measure of reliability is based on percentage agreement, the results of this study do not necessarily support the Olsen and Shorrock (2010) argument for reduced consensus in sector specific variants. Whilst the overall percentage agreement for all seven coders failed to meet the acceptable minimum threshold of 70%, agreement between the separate group of coders remained constant in each case study (83%). Far exceeding the minimum threshold, the ECFA coders not only demonstrated an improvement at the causal category levels but in the case of CS2, total agreement (93% - 100%). At the causal sub-category level both groups demonstrated an improved level of agreement between the two case studies which was greater amongst the ECFA group of coders (72% – 77%).

As can be seen, the initial application of the HFACS in CS1 yielded unreliable results when using the Krippendorff Alpha diagnostic. This is also true of CS2 although, there is some significant evidence of a strengthening of agreement between both case studies, particularly at the HFACS levels of Preconditions of Unsafe Acts and Unsafe Supervision. Whilst analysis using percentage agreement is also below an acceptable threshold of reliability, albeit slightly there is also some evidence of strengthening of agreement in the selection of nanocodes.

There are several factors that can influence these results that represent limitations in the chosen research approach. Not least the most prominent of which is familiarisation of coding participants with the application of the HFACS taxonomy. This and the influence of variance of academic opinion regarding the efficacy of the chosen diagnostic are captured in the general discussion of Chapter 7 below. However, as the results of Study 1 demonstrate the dominance of decision-based and skill-based errors, figure 5.2 above demonstrates how they also dominate at the Unsafe Acts level of failure of the HFACS analysis of the two case studies in this study. This triangulation of results is further examined in Study 3 of the following chapter where the real-life experiences of injured parties at their ‘moment-of-choice’ are subject to qualitative analysis.

6. STUDY 3 – INJURED PARTY EXPERIENCES (RQ1, RQ2).

6.1 Introduction.

This final study sets out to examine an Injured Party's (IPs) own introspective recollection of the decision-making episode that resulted in their injury. Here the intention is to use thematic analysis to explore the environmental and contextual characteristics that influenced judgements, decisions, and actions at the 'moment-of-choice' and the utility of the chosen action that resulted in the deficit outcome. The degree of risk influencing the choice that resulted in the deficit outcome is also examined by comparing the nature of the activity being undertaken at the time of injury with the definition of critical activity established in Chapter 3 – *"circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome".* The study will also serve to triangulate the active error judgements applied by the participating subject matter experts of Study 1 (Figure 3.2, page 80) which are also manifest in the results of the Human Factors Analysis and Classification System (HFACS) used in Study 2 (Figure 5.2, page 167).

Aspects of the first research question (RQ1) were first explored in Study 1. Here it was found that the unintended outcome of the 'moment-of-choice' could mainly be attributed to either skill-based or decision-based errors. Skill-based errors were in the majority and more likely to result in less severe injury. Skill-based behaviour relies on the acquisition of knowledge and assimilation through training and along with repeated application, represents experience. Decision errors represent a failure to fully understand a situation and are largely a result of a lack of situation awareness. Both skill-based and decision-based errors expose the knowledge, skill, understanding and experience (competence) of the IP at the 'moment-of-choice'.

The literature review of Chapter 2 examined the architecture of error and established the error management context of the Fire and Rescue Service (FRS) emergency response domain which further influenced the deductive analyses of Study 1 and Study 2. The methodology of Chapter 3 explains how the planned approach for obtaining injured party experiences was based on the retrospective interview of the Critical Decision Method (CDM) (Klein, Calderwood and McGregor, 1989). First used by Klein, Calderwood and McGregor in their original study of fireground commanders the CDM focuses on non-routine cases which were considered to be a rich source of data. The CDM is specific to a particular event and requires the participant to reflect on their decision(s) (Klein, Calderwood and McGregor, 1989). Salmon et al (2011) published a practical guide to the application of accident analysis methods where they reviewed the CDM. The CDM is designed as a semi structured interview technique which uses a series of probe questions to elicit information on the cognitive processes that influence decision making. The CDM is particularly suited to exploring the 'moment-of-choice' because *"analysis effort is focussed on explaining human operator decision making prior to and during"* an accident or injury causing episode (Salmon et al, 2011:16).

The cognitive probing of the CDM also allows focus on the knowledge, skills, understanding and experience (components of competence) applied by IPs during a critical decision-making activity. However, as explained in the methodology of Chapter 3, and further discussed in Chapter 7, given the reticence of the gatekeepers and IPs involved in Studies 1 and 2 to participate in a programme of semi-structured interviews, the CDM question set was instead used alternatively in the construction of the online survey questionnaire used in this study.

6.2 Questionnaire Construction.

As explained above the reticence of both gatekeepers and participants involved in Study 1 meant they would no longer be the sample group of this study. Consequently, being an open access online survey, it would be open to participation by any member of an FRS injured whilst in attendance at an incident since 1st April 2012. This may also mean that some participants may no longer be serving members of an FRS or in some cases undertaking a different role than that at the time of the injury they describe. It would also have to accommodate the likelihood that the questionnaire would migrate to countries other than England and the devolved administrations of the UK.

The analyses of Study 1 and Study 2 informed the construction of the survey questionnaire which comprises 40 questions divided into eight domains of interest framed around a) the individual IP; b) their injury; c) their decision; d) the approach taken in making the decision; e) the information used in making the decision; f) recognition of previous experiences/learning; g) any additional environmental/contextual influences; and h) reflection. The first domain established understanding of the fundamental demographic characteristics of participating IPs. The second offered the opportunity to record basic temporal data, incident type and injury severity. Here IPs were also offered the opportunity to record additional context of the circumstances of their injury. The following five domains were largely influenced by Endsley's three levels of situation awareness (SA), (1995), the perception of elements in the environment; comprehension of the current situation: and the future state once a choice was made. The influence of any priming effect of previous experiences (RPD) was also explored before the final domain gave IPs the opportunity to reflect on their chosen action and outcome(s).

As described in the methodology of Chapter 3 (Sub section 3.4.3), the question of sensitivity and the likelihood that recalling an injury causing accident could trigger an emotional response would still need to be addressed. Consequently, the opening question asked participants to make a selection that would confirm that they had access to mental health and well-being support services:

1) I am familiar with my service arrangements for seeking help and support in the event of traumatic or emotional response to participating in this survey.

2) I am no longer serving with a Fire and Rescue Service, but I am familiar with arrangements I can make for seeking help and support in the event of traumatic or emotional response to participating in this survey.
3) I am not familiar with any arrangements I can make for seeking help and support in the event of traumatic or emotional response to participating in this survey.

Selecting the third choice took participants to a panel that explained that they would be unable to participate in the survey:

> *"Unfortunately, in these circumstances you will not be able to participate any further in the Firefighter Injury Survey. The University is grateful for your willingness to participate but has to put your health and well-being first and would hope you understand why this measure is necessary. If you would like to discuss this further please contact the researcher directly: (email address)."*

Construction of the questionnaire and usability testing was conducted in late 2017 and the Bristol Online Surveys link to the questionnaire was released January 2018 using two social media platforms, LinkedIn, and Facebook. Three Facebook groups: Firefighters UK; Global Firefighters; and UK Fire News, with an excess of 8,000 members serving the common interests of FRS personnel of all roles agreed to promote the study and include the survey link. In addition, three FRS sector web sites were also used, Firefighter Safety Research, High-Rise Firefighting, and Tall Building Fire Safety Network with a combined excess of 1,500 subscribers. Two widely circulated and popular fire sector journals/magazines Fire Magazine and UK Fire each published a short editorial which included the link to the questionnaire. One of the FRS representative bodies, the Fire Officers Association also circulated the link to its entire membership.

Table 6.1 Critical Decision Method (CDM) decision elements and probe questions adapted from Salmon et al (2011:18) and applied in Study 3.

Questionnaire Theme	Decision Element	ID	Probe Question
INJURY	Goal Specification	GS 1	What was your specific goal/objective at the time you were injured?
DECISION	Decision Making	DM 1	Was there any time pressure involved at the time of your decision?
APPROACH	Cue Identification	CI 1	What kind of things did you look for when you made your decision?
		CI 2	What prompted you to make your decision?
		CI 3	How did you know when to make the decision?
	Expectancy	EXT 1	Were you expecting to have to make this specific decision?
INFORMATION	Information integration	II 1	What was the most important piece of information you used to formulate the decision?
	Situation Awareness	SAW 1	What information did you have available to you at the time of the decision?
		SAW 2	What information did you use in making this decision and how was it obtained?
	Situation Assessment	SAS 1	Did you use all of the information available to you when formulating the decision?
		SAS 2	Was there any additional information that you might have used to assist in the formulation of the decision?
		SAS 3	Did you consult with others whilst you were assessing the situation?

Table 6.1 Critical Decision Method (CDM) continued.

INFORMATION	Options	O 1	Were there any other alternatives available to you other than the decision you made?
		O 2	What other courses of action were considered or were available?
		O 3	How was the option you took selected, and any alternative rejected?
	Decision blocking/stress	DB 1	Was there any stage during the decision-making process in which you found it difficult to process and integrate the information available?
RECOGNITION	Analogy/ Generalisation	AG 1	At the time did you recall a previous experience in which you've made a similar decision?
	Experience	EXP 1	Did this decision fit a standard scenario, had you been trained for dealing with the specific situation?
		EXP 2	What specific training/experience was necessary or helpful in making this decision?
INFLUENCE	Influence	EXP 3	What training/knowledge or information might have helped you in making this decision?
REFLECTION	Expectancy	EXT 1	At that moment in time, were you expecting to make such a decision?
	Conceptual	C 1	Are there circumstances where your decision may have turned out differently?
		C 2	What would have changed the outcome of your decision?
	Decision Making	DM 2	How long did it take for you to actually make the decision, did you get straight to it?

6.3 Study 3 Analysis.

When conducting an analysis Salmon et al (2011) advise researchers using the CDM to follow a generic procedure which first involves defining aims and selecting cases, questions, and participants. Having done so, interviewer(s) and participant(s) should then compile a sequential representation of the incident and the significant events. Once the incident has been described the final generic steps of the CDM process are to conduct interviews, transcribe probe responses and analyse the results. Whilst the survey questionnaire used in this study would satisfy this process, where incident description was concerned, given the sensitive nature of some of the events the participating IPs would be reflecting upon and the potential for narrative responses to vary in length and quality, it was decided to set the need for detailed incident description aside. In order to elicit more specific injury explanation, the second domain included a context question (Q13) which asked IPs to describe what they were doing at the time of their injury.

The focus of the survey questions was both contextual and diagnostic. The contextual focus being on factors that may have influenced the IPs decision and the diagnostic on how they made sense of those influences. Consequently, the analysis not only uses quantitative methods to explore aspects of participant responses but given the pragmatic philosophy of this research, the intention was also to use thematic analysis which is said to be compatible with the pragmatic approach (Parkinson et al 2016:16). As a method of qualitative analysis thematic analysis has matured into what is now described as a widely used and common approach for identifying significant patterns and repetition within a data set (Braun & Clarke, 2006, Bryman, 2012). Its flexibility assists the research approach by exposing both similarities and differences across a data set which will further add to understanding the 'moment-of-choice'.

Guided by Braun and Clarke's (2006) six phases of thematic analysis, to first gain an appreciation of scope and satisfy the need for familiarisation with the data, all responses were initially scrutinised twice. This preliminary scrutiny revealed compatibility with and served to triangulate aspects of the earlier deductive analyses of Study 1 and 2 relating to the presence of decision, skill and perception errors and violations. Initial codes were then generated around these descriptors. Participant responses were entered into a Microsoft Excel spreadsheet with columns coded by question numbers under each domain heading and rows representing participant responses. Both questions and responses were recorded verbatim as concealed comments visible only when the corresponding cell was selected. Derived from the Active Error Descriptors (AEDs) of Study 1, in several cases multiple codes applied to an individual response. Subsequent scrutiny then refined this initial coding process to capture the dominance of environmental and contextual influences on the 'moment-of-choice'.

Across all eight domains, 18 questions required binary yes/no responses and were coded as such. Preliminary inductive analysis of the remaining 21 questions resulted in a total of 84 codes in the form of single word labels. Following this preliminary coding process these initial labels were further analysed for repetition and recurrence and any similarity in meaning resulting in the initial creation of themes. This revealed a consistency across the entire data set influenced by the relationship between the AED codes and the contextual influences described in each participant response. Refining this initial theming identified three main factors that in some way influenced the 'moment-of-choice' – emotional, cultural, and experiential. Consequently, in the results section that follows emotional, cultural, and experiential influences form the key themes of the analysis of the cases under scrutiny. Closing summary reports their influence on the judgements, decisions, and actions at the IPs 'moment-of-choice'. However, as explained in Section 6.5 below, the actual analysis was subject to unexpected default. Theming and subsequent results instead emerging from a process more closely aligned to that of content analysis.

6.4 Study 3 Results.

Where participant responses are used for additional context, in order to understand relevant aspects of their demographic background each quotation is suffixed with an individual profile code derived from their responses to the first two domains. The profile code identifies the participant by using the last three digits of the unique number generated by the survey software and indicates if the response was made to a CDM probe question or a supporting context question (Table 6.2 below).

The first two domains are about the individual IP and aspects of their injury and are largely comprised of demographic questions. For the purpose of triangulation descriptive comparison was made of the demographic, injury severity and temporal profile results of Study 1 (Table 6.3 below). The initial comparison was based on the responses of all 30 IPs participating in the survey. However, a context question (Q9) of the second domain asked participants to identify the type of incident they were attending at the time of injury. Preliminary scrutiny of responses identified that out of the six optional incident types, three participants selected ‘other’. In their supporting text entry two indicated their injury occurred during training and one whilst "*Conducting hydrant testing*". An additional participant made an incorrect selection which indicated attendance at an incident, but the corresponding text entry clearly described how the injury occurred during a training activity. A further three participant responses described injuries sustained whilst responding to an incident. The questionnaire was specifically designed to elicit information from IPs that had sustained injury whilst in attendance at an incident, access to the questionnaire via an email link made this clear. Consequently, the seven participant responses described above were excluded from the analysis.

Of the remaining 23 participants in the study only two were females (7%) which is proportionate to Study 1. The age range of participants also demonstrated quite some life experience the youngest being 21 and the oldest 51 (M36.4, SD 9.1). Experience represented by length of service ranges between 1 and 27 years and the mean (M12.1, SD 7.1), is similar to the five-year competence threshold of Study 1 (M14.5, SD 7.8) with 90% having more than five years-service. The roles of IPs reflected similar population sizes to Study 1 as did the duty system and the shift being worked at the time of injury with firefighters being in the majority.

Table 6.2 Profile codes used to identify relevant participant background characteristics.

Source		Code
Probe Question		P + ID Number
Context Question		C + ID Number
Experience	< 5 Years	E 1
	5 - 9 Years	E 2
	10 - 19 Years	E 3
	> 20 Years	E 4
Role	Firefighter in Development	R 1
	Competent Firefighter	R 2
	Crew Manager	R 3
	Watch Manager	R 4
Injury Severity	No Time Loss	S 1
	< 7 Days	S 2
	> 7 Days	S 3

Unlike Study 1 only two incident types are associated with the 23 IPs of this study. 19 were fires and the remainder Road Traffic Collisions (RTCs) which would indicate a similar distribution of these incident types to that of Study 1. The severity variable concludes the descriptive analysis and indicates the majority of injuries resulted in time loss with the greater number being an absence of more than seven days.

The second domain includes three context questions and the first CDM probe question. It is here the result of the thematic analysis begins and, in each case, whether a CDM probe question (Table 6.1 above) or context question, where appropriate the nature of the question is also explained. Where binary yes/no responses are discussed, their percentage is also given.

6.4.1 Emotional Influences.

Literature review explores the FRS error management context from the perspective of the psychological precursors of the emergency response domain that impact the 'moment-of-choice' (Chapter 2, section 2.7). One such precursor, arguably the most influential, is the expression 'Persons Reported' (PR). When it is known that lives are in danger, whether trapped by fire or some other circumstances, the expression PR is commonly used to indicate the involvement of victims in need of rescue. Of the 23 cases in the study, eight referred to the involvement of PR in their responses and two to the involvement of casualties. Often made known at the time of call or whilst en route the expression PR is an influential environmental cue, one which has the effect of intensifying the many stimuli of emergency response. Such a cognitive stressor is known to evoke an emotional response in those likely to become involved in search and rescue (Rahman, 2007). There are two dominant theories of sense making that establish the importance and influence of environmental cues such as PR in the process of judgement and decision making, recognition primed decision making (RPD), and situation awareness (SA). However, whilst the difficult and sometimes harrowing situations firefighters experience are widely acknowledged in the research literature, there is a dearth of scientific literature examining the emotional demands experienced by firefighters in the emergency response domain (Rhys-Evans, 2019).

Literature review explains how, representing the knowledge and experience components of competence and influenced by environmental cues, RPD focuses on the cognitive process where choice emerges from the recognition of previous experiences or situations that are typical and familiar (Klein, 2004).

Table 6.3 Comparison between demographic injury and temporal variables of Study 1 and Study 3 based on all 30 responses to the survey questionnaire.

Variable	Category	Average Age		*n*	%	Study 1 %
Gender	Female			3	10	8.9
	Male			27	90	90
Age	Firefighter	34.5	40			
	Crew Manager	39.4	42.5			
	Watch Manager	46	45.5			
Length of Service	< 5 Years			6	20	10
	5 Years or more			24	80	90
Role	Firefighter (Development)			5	16.5	74*
	Firefighter (Competent)			17	57	
	Crew Manager			5	16.5	14
	Watch manager			3	10	9.9
Duty System	Whole Time			27	90	89
	On Call (Retained)			3	10	10.2
Generic Shift	Day			18	60	62.4
	Night			12	40	37.6
Incident Type	Fire			22	73	68.4
	Road Traffic Collision			4	13	18.1
	Water			1	3	1.4
	Other Non-fire			3	10	12.2
Severity of Injury	No time loss			10	33	68.6
	Less than 7 days absence			7	23	9.4
	More than 7 days absence			13	43	21.9

** The five-year Length of Service threshold was generically applied in Study 1. Questions relating to development/competence status were specific to Study 3*

In a similar way, acting as a precursor to the decision-making process, the acquisition of SA is said to occur on three levels, the perception of elements (cues) in the environment, comprehension of the current situation and projection of future status (outcomes), where goals are formed (Endsley and Jones, 2012). With both RPD and SA the environmental cues invoke a process of mental simulation and modelling from which a course of action emerges. Endsley and Garland (2008) posit that goals are central to understanding a situation and that a decision maker will seek the information needed to decide on a plan of action to achieve the desired goals.

The first CDM probe question of the survey is within the injury domain and asks an IP to identify their specific goal/objective at the time of their injury. Nine responses refer to persons, persons reported and search and rescue and in one case:

"To release trapped occupants of a vehicle"
[764, P/GS1, E1, R1, S1]

An external stimulus or environmental cue such as PR, where life is believed to be under threat can invoke what has been described as the predator prey response (Rahman, 2009). In terms of PR, the rescuer recognises the victim as the prey and the life-threatening cause of entrapment the predator. Rahman also explains how emotions direct decision making and have an implicit influence on the 'moment-of-choice' which can result in unintended outcomes (Rahman, 2009: 2). With victim rescue being the main focus of attention this in turn can create what is described as an attentional bias (Rahman, 2009:3/4). In their analysis of the circumstances that resulted in the deaths of 19 wildland firefighters, Schoeffler, Honda and Collura (2021) associate this with the existence of 'destructive goal pursuit' where potential hazards in the form of environmental cues can go unnoticed or are even ignored and warn that *"Goals once set are hard to abandon…they cause people to take risks they may not think to take otherwise."* (Schoeffler, Honda and Collura, 2021:121). This is a cognitive influence that is also variously described as tunnel vision (Bayer, 2010, Cavnor, 2018) and goal or task fixation (Bayer, 2010). Which would suggest that recollection of previous incidents can also create self-imposed stimuli leading to task fixation as described in this account of the influence of PR on the ‘moment-of-choice’:

> *“This was a derelict house and the incident was not made ‘persons’ by the IC. However, past experience of both myself and my BA partner indicated that local children often played in any derelict properties in the area so a full search was required”*
> [945, P/CI1, E2, R2, S2]

In contrast, a second IP who refers to the cognitive stressors of time pressure and urgency when dealing with fire in a derelict house, makes no mention of the potential for PR. The IP does mention previous experiences where similar decisions to that which, on this occasion, resulted in injury were made:

> *“Standard layout of a standard 2 storey house to which I had previously attended numerous house fires out”*
> [243, P/AG1, C/33a, E2, R2, S2]

In the first instance the IP indicates that the IC did not create the PR stressor that resulted in action leading to injury. In the second case the decision leading to the action that resulted in injury was made by someone else although the IP confirmed involvement in the decision-making process.

The first of these two cases demonstrate evidence of task fixation. Based on previous experience(s) the mental model and albeit self-imposed environmental cue – PR, influenced the dominant goal – to reach the first floor of the property to conduct a search and possible rescue of children who ‘may’ have been playing in the building. However, the IP adds additional context and reveals:

P/GS1 *“Ground floor had flashed over...* [and was] ... *100% involved”.*

P/SAW2 *“We hit it initially from the outside & then progressed in, using a 19mm hose reel”.*

P/CI3 *“... and having knocked the fire back (not fully extinguished) on the ground floor we needed to progress upstairs to search”.*

P/SAW2 *“The fire had started to spread up the stairs but the 1st floor was not alight at the time of arrival”.*

P/GS1 *"As we progressed up the stairs to the first floor the ceiling collapsed showering us with debris".*

P/CI2 *"Although this was never made persons reported the decision to progress upstairs was driven by the need to search for any casualties (no casualties found)".*

This sequence of responses would support the existence of destructive goal pursuit or task fixation and demonstrate how potential hazards in the form of environmental cues can go unnoticed or are even ignored (Schoeffler, Honda and Collura, 2021:121).

Further evidence of task fixation involving the emotional cognitive stressor PR is found in the accounts of those responsible for the safety of firefighters – their immediate supervisors. In this case [228, E2, R3, S3] the IP suffered serious injury:

P/GS1 *"To get access to rescue persons involved in fire".*

C/Q13 *"Lowering myself over a wall to gain access to property".*

P/CI2 *"Couldn't see another way to get to the house and second pump hadn't arrived. Member of public told me someone was in the house and smoke was coming out of the windows".*

C/Q30 *"I told them someone was in house and I was making my way over wall. 3 persons went over wall I was the only one to hurt myself".*

In a second example of dealing with PR with a fatal outcome the IP describe the influence of previous experience(s)

> *"It was automatic reflex based on experience, make things easier. make them safer, manage the situation. unfortunately The Kitchen door was of a lot better level of security for a normal council property which by my method of entry caused the physical injury.* [596, P/CI3, C/Q20, E2, R4, S3]

Unlike PR when dealing with fires whether informed at the time of call, whilst en route or in attendance, past experiences of the sights and sounds of RTCs create more immediate environmental cues, cognitive stressors, and stimuli

> *"I knew that of three occupants, 1 had been released, 1 was dead and the driver was in a bad way that it became clear quickly that this would be a difficult operation".* [764, P/SAW1, E3, R2, S1]

In this case, due to the additional cognitive stressor of urgency created by another (Helicopter Emergency Medical Service Doctor), the IP was not wearing facial protection whilst working inside a crashed vehicle very close to the casualty. In the subsequent process of extrication, the casualty coughed volumes of blood into the face of the IP. Consequently, the injury was treated as exposure to a pathogen. In this account exaggerated task fixation was created by medical expert opinion: *"I knew she was critical but the doctor made her release priority".* (P/CI3, Q20), the IP also concedes that *"PPE wasn't correct but the casualty needed rapid extrication".*
(N.B. PPE is the acronym used to describe generic personal protective equipment such as safety headwear, footwear, fire, and chemical resistant clothing).

In response to questions of the recognition domain this IP confirms he had no previous similar experiences either at an incident or during training. When responding to the probe question about training or knowledge that may have helped (P/EXP3, Q37a), he replied:

> *"Recognised prime decision making, previous training helps but not realistic at times".*

Once again, reflecting on his choice, the IP stated that in the same circumstances he would do the same things again (C/Q38).

When dealing with the emotional stressor of PR additional stress exists in the need for urgency – the need to save the prey from the predator as quickly as possible as one IP demonstrates:

> *"Urgency was the main factor but also timing/teamwork. The BA team were still starting up so if I opened the door they would have been able to enter straight away rather than have to delay and open it themselves.*
> [818, E2, R2, S3]

Not only is the need for urgency a powerful environmental cue so too can it contribute to task fixation. Literature review explains how the foundation of RPD emerges from studying the decision making of experienced fireground commanders under conditions of extreme time pressure (Klein, Calderwood & Clinton – Cirocco, 2010). Only five of the participants in this study would meet the role description of 'commander'. The remainder are firefighters with varying degrees of experience who are also the primary locus of interest of this research.

The second CDM probe question falls under the decision domain (DM1) and asks if there was any time pressure involved at the 'moment-of-choice'. 16 responses confirmed this was the case. All but two of the cases that involved PR are included in this group. In response to the first CDM probe (GS1), the first such case [089, E4, R2, S3] is injured inside a residential property *"searching for persons".* After confirming the decision which resulted in injury was made by someone else and he took no part in the decision-making process (C/Q17a), this participant offers few responses to the remaining questions making largely binary choices until the penultimate domain which is about things that may have influenced choice at the time. Here the IP indicates he did not have sufficient knowledge for the decisions and actions that were taken at the time (C/Q36). In response to the influence domain CDM probe (P/EXP3) the IP suggests that training in a specific activity (in this case tactical ventilation) may have helped in the decision-making process. However, when reflecting on the decision that resulted in injury this IP creates some contradiction and indicates that in the same circumstances the same choice would be made (C/Q38), and at the 'moment-of-choice' he was expecting to have to make such a decision (P/EXT1), a decision he made instantaneously (P/DM2) and that *"training & being more informed"* (P/C2) would have changed the outcome of the decision. These closing selections would question the knowledge, skill and understanding (competence) of the IP and suggest a skill-based error resulted in injury.

The second IP associated with PR that indicates there was no time pressure involved in making the choice that resulted in severe injury [378, E4, R3, S3] describes the goal at the time was *"searching for persons"* (GS1). However, the actual task involved pulling the largest diameter hose carried on a fire engine (each length of which weighs 100 kilograms when fully charged with water under pressure), up an external metal staircase for firefighting purposes (C/Q13). This IP identifies his role as a Crew Manager and that the choice at the time was entirely his own (C/Q17). Responses to probe questions of the approach domain would indicate that whilst the goal may have been to search for missing persons, some element of confusion about the dominant goal exists:

P/CI1 *"The hose had to be pulled up the metal staircase to reach the fire".*
P/C2 *"We had a goal/objective to achieve".*

P/C3 *"From the position we were at we could not tackle the fire until we pulled the hose to the top of the metal staircase".*

Conceding that there was an alternate approach to be taken involving additional resources that may have helped with chosen action the IP indicates:

P/EXP3 *"Another crew to assist in dragging the hose would possibly have helped".*

Nevertheless, the IP also indicates that in the same circumstances he would make the same choice again (P/EXT1) and despite acknowledging the potential value of seeking help with the task, the IP posits that there are no circumstances where the decision would have turned out differently (P/C1). Whilst this would reconcile the original time pressure response not being associated with search and rescue, so too would it demonstrate the influence of task fixation in positioning the hose for firefighting.

The predator-prey dyad also acts as an emotional stimulus when firefighters themselves become the prey, when they face imminent threat to life such as when caught or trapped by fire conditions. These are circumstances where their own adversarial situation substitutes for the role of predator (Rahman, 2009:4) and the dominant goal becomes escape or urgent self-rescue as one IP explains:

> *"Having searched for a missing person and following a sudden deflagration of the fire, we were trying to escape the effects of backdraft".*
> [265, C/Q13, E2, R2, S3]

(N.B. Backdraft occurs when a fire has consumed most of the oxygen in a burning compartment and whilst still burning is only able to smoulder. Any sudden supply of oxygen such as with window failure or door opening causes the smouldering fire to ignite with explosive force).

In this case the IP is a member of a search and rescue team on the fourth floor of a residential high-rise building. He observes an aerial appliance at street level below and driven by the fight or flight response to threat sustains severe injuries whilst breaking open a secure window in order to bring attention to their predicament and urgent need for rescue.

An unexplained anomaly of this case is that in response to the alternative choice probe question of the information domain (P/01, C29), the IP confirmed there was an alternative choice he could have made. However, the following context questions that would have explained what this was (C/Q29a/b) were left blank.

The majority of these cases have indicated that despite their choices resulting in injury, no matter the severity, in the same circumstances they would do the same thing(s) again. Of the 23 cases in the study only three indicated they would not. In each case they were working under their own volition and whilst they were expecting to make their choice at the time, they concede there were circumstances where their decision may have turned out differently (P/C1, Q40). In explaining what would have changed the outcome of their decision each gave responses that would suggest a lack of SA:

> *"If I'd been operating from a more external position or using a different tool (heavier water) to accomplish the task then I may not have been in the immediate risk zone for falling debris such as the heated nail".*
> [337, E1, R1, S1]

> *"Fire growth".*
> [429, E2, R2, S1]

> *"If I had cleaned the window of glass or attempted to untie the knot further away from the scene".*
> [524, E1, R1, S3]

Whilst in each case aspects of level 2 SA - elements of the environment, are identified and awareness of their influence may have resulted in a more desirable outcome none of these cases were associated with the emotional stressor PR. Although, the case that resulted in the most severe injury did involve an element of urgency which, as discussed above, can lead to task fixation. However, two of these cases described circumstances where stigma arising from cultural influences may have contributed to the outcome. Cultural influences are considered in the following section. This section closes with one case that exposes not only the emotive nature of the environmental cue PR but may also reveal a cultural perspective that could influence the 'moment-of-choice':

> *"I don't give a damn about my safety when a child or my crew is in jeopardy I will do what I have to do ... to ensure their safety".*
> [596, E3, R4, S3]

6.4.2 Cultural Influences.

The literature review of Chapter 2 explains how socio-cultural components of an organisation can influence the potential for violation of safe working practices. Study 1 (Chapter 4) further considers how a supervisory regime can enable routine violation. The continuum of consequences (Table 4.2, page 123) explains how, at the level of near misses, where no physical injury occurs, group culture may adopt a title or nickname for the actor(s) involved who, in the early years of their career may not report injury to avoid such stigma. Study 1 also briefly considers under-reporting of injury amongst female firefighters influenced by the stigma of perceived weakness. The summary of Chapter 4 further associated stigma with under-reporting amongst supervisors and managers.

Consequently, the theme of cultural influences on firefighter injury is explored from two perspectives, the organisation, and the group. In doing so, conventional practice would first set out to define culture in the context of this study and the research literature contains many such definitions. Amongst them is one described as the best known which is also adopted for this section of the study – *"the way we do things around here"* (Deal & Kennedy, 1982: 4, 59/60, Hopkins, 2006: 876), which is applicable to both organisation and group socio cultural practices.

From an organisational culture perspective, in the small sample of this survey 11 cases (48%) describe or infer the influence of a procedural expectation which would be representative of organisational artefacts and policies in two domains of interest of the survey, the approach taken, and information used. In exploring the approach when making the decision or choices that resulted in injury (P/CI1), five cases either made direct reference to the identification of hazards which is associated with the application of risk assessment itself or the need to adopt a safe system of work. This would indicate that all were aware of the need to adopt the safe working practices and procedural expectations of the organisation when selecting the system of work and control measures at their 'moment-of-choice':

> *"I did not thoroughly risk assess"*
> [337, E1, R1, S1]
>
> *"Safe systems of work"*
> [171, E3, R4, S1]
>
> *"Dynamic risk assessment continually, accidents can't be foreseen"*
> [966, E1, R1, S2]
>
> *"Hazards within the building, i.e., slips, trips, falls, fire, building collapse, etc., etc."*

[243, E2, R2, S2]

"Hazard identified, control measures identified"
[476, E3, R2, S2]

Similarly, in response to questions about the information used to make their decision all but one of those cases identified either a standard operating procedure, safe person guidance or, as above, an aspect of risk assessment:

"I was fully aware of the safe person concept..."
"Remain in full PPE"
[337, P/SAW1, P/02, E1, R1, S1]

"It was a logical control measure to increase safety"
[476, P/II1, E3, R2, S2]

Context question 31 of the information domain asks if the IP followed a recognised process to select the chosen course of action, six responses confirmed this to be the case naming the process, and once again Dynamic Risk Assessment profiles:

"Dynamic risk assessment and safe person concept"
[228, E2, R3, S3]

"SOP's and MOU's with partner organisations"
[171, E4, R4, S1]

"Safe systems of work"
[757, E2, R2, S1]

"SOP's ops procedures"
[966, E1, R1, S2]

"Decision control process and dynamic risk assessment"
[227, E3, R4, S1]

"Fire Service BA procedure"
[243, E2, R2, S2]

Dynamic risk assessment"
[519, E1, R2, S3]

It is widely accepted that culture is a construct that distinguishes groups according to behaviours (Strauch, 2015), and that an organisation will contain a number of sub-cultures with professional, operational, moral and ethical values that influence behaviours (Gordon, Kirwan & Perrin, 2007) that in turn can impact on safety (Hopkins, 2006). The definition of culture used above to simply explain the meaning of culture applied in this study would support the existence of separate group sub-cultures within an organisation culture. This would be evident in the way a group of on-call firefighters, or one or more watches at a fire station would adopt their own interpretation of organisational practice. In the emergency response domain, when at an incident this would be representative of a routine violation which is one of five AEDs used in Study 1 and identified as a sub-category of the Unsafe Acts level of the HFACS used in Study 2. In the final excerpt of section 6.4.1 above are the words of the leader of just such a sub-culture who influences behaviours, or the way things get done – a Watch Manager.

Of the 23 cases in this study five have formal group leadership roles, three Watch Managers and two Crew Managers. With one exception [596], their responses contain little evidence of activities or behaviours that could be described as influencing or being influenced by the group sub-culture of a watch. Amongst the remainder of the sample, one case contains evidence of not only a routine violation that describes culturally influenced behaviour but also how the influence of stigma can result in under-reporting of injury:

> *"At the time, during 'overhaul/make up' I had relaxed dress (as was the culture, no specific permission requested) and had my tunic open at the neck approximately 6-8 inches".*
> [337, C/Q12, E1, R1, S1]

This IP explains how a hot six-inch nail in a fire damaged wooden joist was dislodged by the hose reel jet he was using and fell inside the open tunic burning him on the chest and concludes:

> *"I doused this with copious water at the time and did not report it through embarrassment and fear that I would be punished for not keeping full PPE as appropriate".*

In response to the CDM probe question of the influence domain that asks what training/knowledge or information might have helped in making the decision (EXP3), the IP implicates a lack of supervision. *"I think that in this particular case that correct supervision as opposed to training would have made more impact."* which would once again confirm evidence of an organisation sub-culture. On this occasion, one where routine violation is endorsed by the group leader.

A second case involving a firefighter in his first year of service demonstrates further evidence of task fixation which can be associated with the influence of stigma in a watch culture:

> *"At the time I was focussed on the task in hand and didn't consider the bigger picture, I partly believe this was due to my inexperience and desire to succeed at the task in front of fellow colleagues".*
> [524, P/CI1, E1, R1, S3]

Both IPs concede that in the same circumstances they would not repeat their actions and in each case would adopt a less exposed position to achieve their task.

The two cases above that exhibit evidence of the influence of stigma in the information domain (337, 524) are indicative of desire to be accepted by the more experienced and established members of the group. Each records an experience level below the competence threshold of five years-service at the time of injury. One of these cases is also represented in responses to questions of the approach domain where the lexicon of risk assessment is used implicating a lack of thoroughness in the risk assessment process. By stating that *"... accidents can't be foreseen"*, another case with less than five years-service (966) is making a contradictory statement about the process of Dynamic Risk Assessment (DRA). With only one year service this could represent an acceptable lack of IP understanding. In contrast, cases where experience exceeds the five year threshold (E2) and includes the roles of supervisors (R3/R4), also indicate they followed the process of DRA. Yet they still experienced the deficit outcome of their 'moment-of-choice' which would indicate either an erosion of knowledge and understanding, or the influence of environmental or contextual factors of which they were not adequately aware. In three cases the injury severity level was at the upper threshold (S3).

Okoli et al (2016) posit that *"... the ability to effectively conduct DRA on the fireground lies in utilising existing knowledge, which is largely rooted in experience"* (Okoli et al, 2016:19). The literature review of Chapter 2 describes how, at the rule-based level of cognitive performance previous experiences and working memory are influential in judgement and decision making. RPD is the cognitive process of selecting a course of action based on experiences merged in memory (Klein, 2004). Klein also argues that experiences can be misleading and lead to mistakes (Klein, 1999:34). The FRS also acknowledges that being a 'safe person' is built on behaviours developed with experience (DCLG 2013: 29).

6.4.3 Experiential Influences.

Scrutiny of emotional influences on decision making in section 6.4.2 above describes how environmental cues invoke a process of mental simulation where goals are formed, and choice of action emerges. Section 2.7 of the literature review considers the error management context of the FRS and explains how national operational guidance (NOG) warns that recognition or recall of a previous experience may result in an incorrect matching to the actual circumstances encountered. Describing the influences of this mismatch as 'decision traps', which can lead to a situation going wrong, NOG directs incident commanders (ICs) to consider a heuristic process of 'decision controls' *"before moving to the action phase"* of choice to avoid decision traps (NOG 2021c). As previously stated, experience acquired through practice and knowledge acquired through training are essential components of the mental simulation process of RPD and SA.

The two domains of interest that reveal the influence of experience at the 'moment-of-choice' to the greatest extent, and to a lesser extent, the influence of training are recognition and influence. Of the 23 cases in this study all but one directly cites experience or infers its influence when discussing knowledge acquisition through training. Using a CDM probe (AG1) the recognition domain first asks if the IP can recall a previous experience which involved a similar decision. Of the relevant responses 12 cases confirmed this to be the case. In response to the subsequent probe question (EXP1) about receiving training for the specific situation they are describing, six of the remaining ten cases also indicated this was the case. This would suggest that of the 22 relevant injury cases only four could not be associated with previously acquired knowledge or experience. The influence domain probe question (EXP3) asks what training/ knowledge or information might have helped in making the decision. In response one of these remaining four cases (265) records: "*All my basic training was relevant*". A second IP (764) credited *"Recognised primed decision making"*, adding that *"previous training helps but not realistic at times"*. This would further suggest that only two of the relevant cases had no previous experiences or knowledge of the environmental circumstances where their 'moment-of-choice' resulted in the deficit outcome of injury.

Application of the decision control process (DCP) identified above forms an important part of the demonstration that both crew and watch managers must give before being considered competent to undertake incident command at their level of responsibility. The survey sample includes responses from five such supervisors, two crew managers (CM) and three watch managers (WM). All recalled a previous experience where they made similar decisions.

Of three cases that experienced injury at the more serious threshold a CM with ten years-service describes having taken the same decision and action (228). A second CM with 27 years-service recognises the difficulty of handling the heavy weight that resulted in injury. The third, a WM with 21 years' service concedes he had *"Not just* *one experience* [but] *dozens of fires where entry had to be forced"*. All three indicated that their decision fitted a standard scenario for which they had been trained. In response to probe EXP2 they responded:

> *"Trained in house fires and in using brigade ladders. Also trained in Dynamic Risk Assessment as a crew manager"*
> [228, E2, R3, S3]
>
> *"RTC training courses, Incident Command training, inter-agency training"*
> [171, E4, R4, S1]
>
> *"27 years plus basic training"*
> [378, E4, R3, S3]
>
> *"Training/experience/history of past events"*
> [227, E3, R4, S4]
>
> *"YES/NO... we had done only basic entry simulations nothing of the exact type of security measures as encountered and nothing can prepare you for some incidents or the extra stress that other factors can cause"*
> [596, E, R, S]

In each case, despite going through a decision-making process and taking a course of action that resulted in personal injury, without exception all five supervisory IPs indicated they did not imagine the possible outcomes of their decision which represents the third level of SA. Neither did they consider themselves to be out of their depth. Two of these cases confirmed they had been trained in DRA and incident command despite which, having cited experience and training as being helpful in taking the chosen action, one felt he was not sufficiently skilled for the choice of action (227).

18 of the 23 relevant cases directly cite the influence of experience in making the choice that resulted in their injury and four of the five remaining cases all contain cells coded to the experience theme. Amongst them one [155, E2, R2, S2] is also associated with the emotional stimuli of PR and involves the time critical rescue of a bariatric casualty:

P/GS1 *"... the goal was to remove the casualty to clean air."*

P/CI1 *"The main thing was that this was a casualty rescue and extremely time critical. The casualty was unconscious and not breathing in a smoke filled environment. With the resources available at the time there was very little else that could have effected/changed the decision."*

P/AG1 *"Most of our BA training is based around rescuing unconscious casualties. However, we do not train for casualties that way* [weigh] *as much as the one in this instance."*

On reflection, this IP indicated that in the same circumstances he would do the same thing(s) again but also conceded that his choice at the time may have had a different outcome if a more appropriate item of equipment had been used. What the IP does not indicate in this reflective remark is if the item was available for use at the time: *"A rescue harness would have given another option. Otherwise there was no other decision to be made."*

The three associated cases in this group include one where injury was at the severe threshold [808, E3, R2, S3]. In this case the context indicates the IP is the designated driver of a fire engine at an RTC and making ready the pump to supply water for a fire attack in the event of fire. The IP confirms the activity was influenced by past experience and there was a degree of urgency attached to the task. In another case the IP was using a sledgehammer to force entry through a toughened glass door into a building on fire. The IP describes the choice as the only path available and explains that he had been trained and considered himself competent in the use of a sledgehammer.

The two remaining cases of this group record sustaining no time loss injury. The first [503, E2, R2, S1] involves a firefighter with 9 years' service attempting to gain access to the attic space of a domestic property. The occupier had called the Fire Service to a smell of smoke and the smoke alarm had operated. On arrival there was no sign of smoke on the ground and first floors necessitating inspection of the loft and roof space. The IP explains:

CI2 *"The loft hatch was small and had a ladder already attached. I was unable to use our little/giant ladders to get into the loft due to size restraints."*

Subsequently, whilst using the attached loft ladder the bottom extension came off causing the top extension to fall trapping the IP under his own bodyweight by the hand. The IP confirms he had been trained to climb ladders. However, that training would be exclusive to the use of Fire Service ladders. In this case the HFACS used in Study 2 would categorise the unsafe act as an exceptional violation to which the IP concedes: *"Usually use our own ladders to access a loft"*, the IP also states that in the same circumstances he would do the same thing(s) again which would demonstrate how, an exception can develop into routine practice.

These final three cases expose the use of the CDM probe question set in a survey questionnaire. The opportunity for a researcher to elaborate on important contextual characteristics is restricted to composing additional contextual questions in anticipation of a more informative narrative response. This limitation to the chosen research approach is considered in the discussion of Chapter 7 below.

6.5 Injured Party Experiences – Summary.

Before continuing it is important to explain the unexpected default that occurred in the process of analysis. Whilst thematic analysis is now widely cited as a means of analysing qualitative data, unfamiliar with the practice the researcher was guided by published academic sources (Braun and Clark 2006, Bryman 2012, Parkinson et al 2016).

In an early attempt to establish a logical structure to the analysis and guided by review of the Braun and Clark (2006) six phases of thematic analysis codes were first derived from what at the time was an empiric knowledge of the labels used to identify Active Error Descriptors (AEDs). On every occasion of their application in the previous studies of this research AEDs had been used to identify frequency. The resultant consistency of coding using frequency of AEDs resulted in what are described in this chapter as three main influencing factors, emotional, cultural, and experiential.

However, when taking a more reflexive view after completion, it became apparent that what was manifest in the data and the more latent labelling of themes resulting from the preparation of data for analysis and repeated familiarisation with participant responses, was the prominent influence of AEDs. It is now understood that this influence resulted in an heavy focus on frequency which is more recognisable as an important characteristic of the content analysis technique. Consequently, the summary that now follows should be considered from this analytical default position.

As previously discussed, the original intention of this study was to explore the environmental and contextual characteristics that influenced the 'moment-of-choice' of 93 specific reported injury cases identified in Study 1. Unfortunately, due to the reticence of the participating FRSs and the specific group of IPs, conducting semi-structured interviews with a meaningful portion of the sample was not possible. The alternative of a questionnaire was instead adopted the challenges of which are considered in the discussion of the following chapter. An overview of the study is provided in Table 6.5 below.

In considering the utility of the chosen action resulting in the deficit outcome of injury to the IPs involved, it could be argued that at their 'moment-of-choice' the chosen action made absolute sense and only in retrospect can utility be judged. Here utility lies in the contextual evidence where all but two of the participants mention the presence or perceived presence of victims and the direct or indirect contribution the IP was making during operations to victim safety. Their responses also indicate that in experiencing the same circumstances all but two would do the same thing(s) again. In 10 cases injury was recorded at the higher threshold requiring more than seven days absence from duty, one of which (who never reached the scene of operations), involved extensive periods of hospitalisation surgery and several months of rehabilitation. This would sustain the argument of task fixation being more likely to occur when the emotional stressor PR is the dominant cue, so much so, that despite experiencing the deficit outcome of their 'moment-of-choice' at the time, by implication, half of them would accept sustaining severe injury.

Table 6.4 Providing an overview of Study 3.

Research Question(s)	Overview	Participation
RQ1 RQ2	Designed to probe the decision making of cases experiencing the deficit outcomes of their 'moment-of-choice'. Based on the Injured Parties (IPs) own recollection of the decision-making episode that resulted in injury. Triangulates and examines the reliability and validity of evidence gathered in Study 1. Focus placed on the critical nature of the activity at the time of injury and the active error judgements applied by the participants of Study 1. Uses data to explore the environmental and contextual characteristics and HFs influencing IP judgements, decisions, and actions at the 'moment-of-choice'. Influenced by the Critical Decision Method (CDM). Originally set out to use a program of semi-structured interviews. Lack of response resulted in the use of an online questionnaire. By default, uses content analysis to examine responses.	93 potential participants were identified in Study 1. 13 FRSs agreed to participate which reduced potential participants to 49. Only two participants agreed to participate. Semi-structured interviews were substituted for an online questionnaire. Final analysis is based on responses from 23 participants.

Study 3 also sets out to explore the degree of risk influencing IP choices that resulted in the deficit outcome of injury. Described as criticality, this is achieved by comparing the nature of the activity being undertaken at the time of injury with the definition of critical activity and the chosen action. In making such judgements IPs referred to FRS decision making heuristics such as dynamic risk assessment (DRA) and/or the decision control process (DCP) or the firefighters safety maxim (the maxim).

In the Fire Service error management context of Section 2.7 above, literature review explains how the maxim establishes the risk and benefit criteria for the critical decision making of both ICs and firefighters stating that:

> *"Activities that present a high risk to safety* ... [should be] *... limited to those that have the potential to save life or to prevent rapid and significant escalation of the incident"*
>
> *National Operational Guidance* (2021g)

Neither 'rapid' or 'significant' are defined but National Operational Guidance (NOG) explains:

> *"An example might be a property where fire is confirmed with no persons missing and the fire has not ventilated. Here the crews are unlikely to enter the building until ventilation has been carried out and the risk of backdraught reduced. There is still benefit in saving the building once the higher risks have been reduced."*
>
> National Operational Guidance (2021g)

Although NOG directs the meaning and application of the maxim at both commanders and firefighters it makes clear that it is the IC who will consider the 'benefit of activities' and where risk is high, but benefit is low *"commanders should only tolerate a limited risk to firefighters."* (NOG 2021i). Factors influencing the choice of an IC when tasking the IP are not specifically sought by the questionnaire which focuses instead on their choices and actions when they themselves are performing a task. The influence of an IC is however implicit in an IP's response to the question which asks if the choice was made by the IP or someone else.

Five IPs, all competent firefighters, indicated that the choice was made by another. Four were working under direct supervision and one indicates communicating with the IC. The responses of one case provides no evidence of criticality. Another case demonstrates how an IC did not create the criticality of persons reported (PR), it was instead self-imposed by the IP and was subsequently never found to be applicable.

There were five cases where the IP held a supervisory role, three watch managers (WM) and two crew managers (CM). Two of these had more than 10 years-service and three more than 20. At the time of injury two indicated they additionally held the role of IC which would suggest they were also operating within the expectations of the maxim. All five implicate the environmental cue and emotional cognitive stressor of PR and the need for victim rescue. This would indicate that even those responsible for DRA and acting under the DCP who in turn are responsible for the safety of others fall victim to the emotive stressor of PR, placing their own safety second; and by implication of the maxim, that of their crew(s), to that of perceived or actual victims. This may further demonstrate how emotional response can influence task fixation, create urgency and how supervisors can influence the behaviour of those who follow their lead in the group subculture of a watch or crew.

However, it is the judgements, decisions and actions of firefighters that form the locus of interest of this research. Illustrating that critical decisions are not exclusive to the domain of the IC, there are five cases of firefighters also acting under the emotional stressor of PR, one being a victim of fire himself - the 'person reported', and possibly influenced by the predator-prey dyad.

The introduction of this chapter explains how the analyses of Study 1 and Study 2 informed the construction of the questionnaire used in this study. Summary discussion of Study 1 explains how Active Error Descriptors (AEDs) were used to identify if the unintended deficit outcome of the 'moment-of-choice' could be attributed to a decision based; skill based; or perception-based error or procedural violation influenced by environmental or contextual preconditions existing at the time. Despite the 23 cases used in this study not being representative of the 93 critical cases of Study 1, they also demonstrate evidence of those error types.

IPs holding the role of firefighter indicate they considered the DRA heuristic when making their choice and one of the supervisors describes using the DCP. Despite which they still experienced the deficit outcome of injury at their 'moment-of-choice', an outcome which each heuristic is designed to at least reduce and at best prevent. Whether it is labelled as situation assessment, DRA or the DCP, the ability to recognise and perceive risk is an important part of the mental modelling or cognitive process that results in choice and is essential to understanding and projecting possible future states or outcomes. The ability to be decisive about hazards and perceive risk is inextricably linked to behaviour developed with experience.

Study 1 established a length of service threshold where through the acquisition of knowledge, skill, understanding and experience firefighters could be considered competent. The introduction (Section 6.1) above explains how both decision-based and skill-based errors expose competence of IPs at the 'moment-of-choice'. Along with perception errors and violations they also form the basis of the Unsafe Acts category of analysis of the HFACS used in Study 2.

Based on the organisational practices of the FRSs participating in Study 1 the competence threshold of a firefighter was set at five years-service. Only four IPs failed to meet this threshold. Whilst despite the outcome of their 'moment-of-choice' two of these IPs describe using the DRA heuristic. Signposting the potential for 'rookie' underreporting of injury, the remaining two both indicate that their choices were in some way influenced by their group culture and the risk of stigmatisation rather than risk of injury.

In this analysis cultural influences were approached from two perspectives, the first being the imposed organisational culture of safe practice represented by the artefacts of guidance and the second being the influence of the group culture. The small sample of this study demonstrates how the requirements of some of these artefacts are being violated and can be associated with the deficit outcome of injury. Eight cases offer limited evidence of criticality which would suggest that other preconditions influenced the unsafe act that resulted in injury and reinforce the use of a sector specific HF analysis tool such as the HFACS of Study 2 and the value of an FRS Human factors Analysis Framework (HFAF).

There are two cases where evidence of the influence of a group culture is overtly stated. One IP adopts the practice of the group who routinely relax their personal protective equipment (PPE). Further implicating the effects of stigma and confirming the existence of injury underreporting, this IP refers to embarrassment at sustaining his injury and fear of punishment for failing to observe safe practice. Consequently, the injury was not reported. The second IP, with only one year's service, a portion of which would have included several weeks of basic training before joining the group, refers to *"the desire to succeed at the task in front of fellow colleagues"*. These IPs were relatively inexperienced 'rookie' firefighters at the time of injury. The remaining 14 firefighters of Study 3 had between seven and 20 years-experience indicated by their length of service (M12.8, SD 4.3).

The influence of IP experience(s) is frequently mentioned in responses. Whether acquired through practice during training or simulation or whilst responding to or attending an incident in the emergency response domain, tacit knowledge is essential for ensuring the safe application of skills. Only five of the group of competent firefighters could remember a previous experience where they had made a similar decision, one where their 'moment-of-choice' matched a standard scenario that they had been trained to deal with. None of this group of five held the view that they lacked sufficient knowledge or skill to make the decision and take the chosen action that resulted in the unwanted deficit outcome of injury.

However, nine competent firefighters were unable to recall a similar experience. Despite five stating they had been trained for dealing with such a situation, neither felt they had sufficient knowledge or skill for the decisions and actions taken at their ‘moment-of-choice’. The remaining four cases in this group who were able to call upon a previous experience also indicated they did not have the required knowledge and skill for their decisions and actions. When reflecting on their deficit experiences, participating IPs in the role of firefighter also offered evidence that either their knowledge, skill and understanding was inadequate or there were other environmental or contextual factors that influenced their ‘moment-of-choice’ which resulted in the unwanted deficit outcome of injury. This would indicate that scrutiny using an analysis tool such as the HFACS of Study 2 could reveal some other ‘factors’ involving unsafe acts, their preconditions as well as supervisory or organisational influences that could influence deficit outcomes.

Whilst limited in sample strength this summary establishes evidence that regardless of their level of experience, when dealing with fires and implementing the requirements of an ICs tactical plan, firefighters are also critical decision makers. This study also confirms that they are experiencing the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander.

The general discussion that now follows considers how the findings of the three component studies of this research contribute to understanding and provide answers to three research questions:

> Research Question 1 (RQ1) –
>
> How effective is the FRS at gathering, analysing, and understanding the pre-conditions and human factors of accident causation.
>
> Research Question 2 (RQ2) –

When working without the oversight of a supervisor or commander firefighters may be called upon to make a ‘critical decision’. When doing so, to what extent do they experience the deficit outcome of injury, and what type of active error is injury more likely to result from.

Research Question 3 (RQ3) –

When developing targeted intervention strategies, how effective would a sector specific analysis tool be in supporting the FRS to better understand the active errors, their pre-conditions, and the supervisory and organisational influences of accident causation.

The implications for error management and injury reduction in the emergency response domain of English Fire and Rescue Services are also considered, which are equally applicable to FRSs throughout the United Kingdom. How this research may contribute to knowledge and research of the safety science and psychology disciplines also forms part of the following discussion.

7. Discussio*n* of Key findings, limitations and application of the research to the Fire and Rescue Service.

7.1 Introduction.

The introduction to this thesis states the intention to examine several factors that influence the decision making, actions and behaviours of firefighters when attending operational incidents which can result in either an active injury to themselves or the passive injury of other firefighters. The stated aim of the research is to improve error management and contribute to injury reduction in the Fire and Rescue Service (FRS). In meeting this aim, the research is framed around two objectives. Firstly, to identify the extent to which FRSs gather, analyse and understand the use of data relating to the preconditions, unsafe acts and decision-making deficit of reported operational injury. In particular, the extent to which as critical decision makers, firefighters experience the deficit outcome of their own risk-v-benefit decisions when operating without the immediate oversight of a supervisor or commander. The second objective is to determine if a sector specific analysis tool can be developed and used to better understand the human factors of accident causation and inform targeted intervention strategies. This aim and objectives were examined by the three research questions of the previous page that emerged from investigating the circumstances of an incident that resulted in the death of two firefighters. Despite the unintended and tragic outcomes, the actions, and choices of those involved made absolute sense to them at the time.

The structure of this discussion first considers key findings arising from the results of two studies designed to address the first of the main research objectives described above. The first is described as a Data Capture Study (Study 1), in which 18 (≈ 40%) of the 46 English FRSs participated and provided 417 of the 1,049 (≈ 40%) reported injury cases in the year of the study (2015/16). Here the demographic characteristics of the injured parties (IPs) and supporting the 'common sense' view of Heinrich (1941) found in the literature; the direct causes, acts, and conditions immediately preceding an accident that represent the preconditions of accident causation were obtained for descriptive analysis. This was complemented by a further study (Study 3) which originally set out to examine the introspective recollections of 93 (20%) of the original 417 cases which involved a critical decision-making episode that resulted in the deficit outcome of their injury. The results of each of these studies address the first two of three research questions:

How effective is the FRS at gathering, analysing, and understanding the pre-conditions and human factors of accident causation?

When working without the oversight of a supervisor or commander firefighters may be called upon to make a 'critical decision'. When doing so, to what extent do they experience the deficit outcome of injury, and what type of active error is injury more likely to result from?

The second research objective was to determine if a sector specific Human Factors (HF) analysis tool could be developed for the FRS that could be used to better understand the HF of accident causation, inform targeted intervention strategies, and contribute to a reduction of reported operational injury. Here two case studies were used to explore the application of an analysis tool designed to effectively investigate the HF of accident causation. The Human Factors Analysis and Classification System (HFACS) of Weigmann and Shappell (2003), was used by a sample of the FRS managers that participated in the initial data capture study of Study 1. In response to the third research question (RQ3), the second study explored the applicability of the HFACS to the emergency response domain of the FRS and the potential for development and application of an FRS sector specific variant later described as UKFire-HFACS.

Informed also by issues emerging from the literature review of Chapter 2, the discussion that now follows first considers the key findings of each of these studies. Designed to inform any subsequent/emergent research with similar aims and/or objectives, a separate section then considers the limitations arising from these findings and the approach taken during their research and analysis. Final discussion then considers the implications, application and use of the research findings for error management and FRS injury reduction strategies.

7.2 Discussion of findings of Data Capture and Injured Party Experiences.

Guided by the knowledge that most, if not all English FRSs hold data that could better inform understanding of the influence of HFs, the first study examined several factors relating to the contextual and environmental preconditions that influence the decision-making, actions and behaviours of firefighters when responding to, attending, and mitigating the effects of operational incidents.

The exploration of HFs was facilitated by what is described as the concept of ‘error typing’ where Active Error Descriptors (AEDs) derived from the psychological varieties of unsafe acts (Reason 1990:207) were used to identify if the unexpected outcome of a ‘moment-of-choice’ resulted from a decision-based; skill-based; or perception-based error; or a type of procedural violation. It is these that represent the unsafe acts of accident causation that can influence decisions, actions, and outcomes and result in injury.

Before commencing this discussion, it is important to restate that the locus of interest of this study is the ‘moment-of-choice’ of those FRS personnel serving in the role of firefighter. In support of the assertion in the literature that even a firefighter can have considerable decision-making discretion and accountability (Bourrier 2011, Hopkins 1999). A finding emerging from review of the Naturalistic Decision Making (NDM) paradigm literature is an unintentional bias where researchers use the term firefighter generically (Flin et al 1997, Flin and Arbuthnot 2002, Flin, O’Connor, and Crichton 2008, Pruitt, Cannon-Bowers and Salas 1997, Zsambok and Klein 1997). This thesis argues that to do so is misleading when their research focus is on the judgements, decisions, and choices of those in the role of incident commanders (ICs) and not those serving in the role of firefighters.

7.2.1 Data Capture.

Of the 417 reported injury cases of this first study 314 (75%) of the IPs held the role of firefighter and it is they who, on many occasions, will be tasked to achieve the operational tactics and physical actions of an ICs tactical plan. Often working remotely, in stressful and sometimes emotionally charged circumstances it will be the firefighter who is the first to encounter and react to unknown, sometimes unexpected incident developments and occasionally be required to make a critical decision. No guidance is specifically focussed on the development of the decision0-making competencies of firefighters. Instead, a review of the extant literature for National Operational Guidance (NOG) of English FRSs has revealed extensive national guidance for ICs on judgement and decision-making (NOG 2021a – i). This contributes to the knowledge base and sets the standard against which the initial acquisition and ongoing maintenance of effective performance and competence of ICs is measured (NOS 2021). No such guidance is specifically focussed on the development of the decision-making competencies of firefighters.

This research posits that when implementing the requirements of an ICs tactical plan, particularly during firefighting operations, firefighters are likely to be acting in response to their own judgement and decision-making. This will often be without the direct oversight of their supervisors and commanders who are the group of people required to demonstrate competence in both judgement and decision-making. Supporting this argument is the process described in this research as 'error typing'. Using AEDs as an independent variable, error typing identified the prominence (31%) of reported injury resulting from decision errors. The skill, rule, knowledge anthology of the literature review explains how scientific scrutiny of human factors has produced an extensive architecture of error where there is broad agreement that decision errors result from rule and knowledge-based mistakes (Griggs 2012, Rasmussen 1983, Reason 1990 & 2016, Salazar 2001, Sharit 2012). This research asserts that the dominance of decision errors revealed by error typing establishes evidence of weakness in the judgement and decision-making of firefighters and supports the argument for them having an enhanced level of critical decision-making competence and assessment.

Competence is not only influential to the process of decision-making. For both ICs and firefighters, competence is significantly influenced by skills acquired and refreshed in context-dependent practical situations and heavily reliant on exposure to the challenges and demands of incidents encountered in the emergency response domain (Paloniemi 2006). Nationally published data demonstrates how the impact of modernisation resulted in a significant reduction in opportunities to gain experience in the 'natural' environment of the emergency response domain (see Figures 1.1 and 2.6) (Home Office 2021).

However, to perform competently in the emergency response domain there is also an expectation that firefighters will establish and maintain the skill, knowledge and understanding to perform their duties effectively (HSE 2018). Whilst the aim and objectives of this research focus on judgement and decision-making, the error typing process of the data capture study also identified that reported injury resulting from skill-based errors were in the majority and represented 37% of the sample. This provides evidence in support of the Lamb, Davies and Bowley (2014) argument for the existence and influence of skill fade also affecting the 'moment-of-choice' of firefighters but also draw attention to FRS arrangements for the maintenance and assessment of competence of firefighters.

The data capture study also influenced use of the expression ‘reported injury’, in the context of this research. At the commencement of the data capture study the focus of interest was described as operational injury. At the time, although provided by the participating FRSs, gender of IPs was excluded from separate data analysis. This was largely because FRS role descriptions do not demonstrate a gender difference in the competence requirements of a firefighter, and male and female FRS entrants must meet the same entry requirements. Despite only a small sample (≈9%) of the 417 cases in the study being identified as women, a reflexive experience occurring in the closing stages of compiling the thesis prompted the need for additional literature review. The initial literature review of the architecture of error did not scrutinise socio-cultural influences on accident reporting and the researcher did not consider the likelihood that workplace injury may not be accurately reported which prompted the need for closer examination.

Limited empiric or peer reviewed research exploring the influence of the relationship between gender difference and firefighter injury was found in the subsequent literature review. However, the concept of stigma related under-reporting of injury amongst women firefighters did emerge. This also revealed evidence that, regardless of gender, various facets of stigma can result in workplace injury going unreported. Consequently, to add relevance to this discussion it was felt important to ensure that the existence of socio-cultural influences affecting the under reporting of injury were recognised. In light of the knowledge that some firefighter injury could be going unreported, it was also considered important to amend the title of this thesis.

It was notable that the majority of peer reviewed research into the effects of gender on safety behaviours was found to be of North American origin. A recent international study into the health and wellbeing of women firefighters also found that those serving in Fire Departments of North America were *“more likely to suffer from injury and illness”* (Watkins et al 2019:428). A consistent theme of several studies was that being female and working in the male dominated culture of the fire service could itself contribute to an increased risk of injury (Hollerbach et al 2017). This was more likely to be associated with physically demanding tasks and reluctance to ask for help from colleagues and being seen to be weak. A separate study into the effect of gender on safety behaviours described how female firefighters found the reporting of injury challenging because of the way it contradicts the macho image of the firefighter (Khan, Davis, and Taylor 2017).

Without making any gender specific reference, and relevant to both male and female injury reporting behaviours, Sinden et al (2011) found that ‘rookie’ firefighters felt they needed to earn the respect of their peers which also influenced under-reporting. More generic research of gender differences in the reporting of work-related injury found extensive evidence of under-reporting and that young males were less likely to report injury (Tucker et al 2014). Consequently, the current thesis provides preliminary evidence to suggest this too may apply to the young male ‘rookie’ firefighter.

Applicable to the emergency response domain of the FRS, Probst and Estrada (2010) examined under-reporting of accidents in industries where there is an above average workplace risk factor such as that encountered in the emergency response domain of the FRS. They found that perceptions of an organisation’s safety climate and weak supervision had some influence on injury under-reporting. Focussing on *“... the process by which individuals mitigate the consequences of their own violations of moral standards”*, Petitta, Probst and Barbaranelli (2017:489), also cited the influence of organisational safety culture and how it can lead to accident under-reporting. In support of their argument, they posit that national statistics may not demonstrate an accurate picture of workplace injury. Prior to this discovery and supporting the argument of Petitta, Probst and Barbaranelli (2017), evidence of FRS under-reporting was discovered when it was found that only 60% of the injury cases provided by one of the participating FRSs were accounted for in the national report published for the year of the study (Home Office 2021).

Under-reporting of workplace injury is also described as a common trait by Pransky et al (1999) that can be influenced by fear of reprisal and job loss. This position further influenced the view that circumstances that lead to the existence of stigma related under-reporting amongst female and rookie male firefighters could also apply to the under reporting of injury by supervisors and managers during their early career development. A need to earn respect of peers and subordinates, fear of judgement by superiors, loss of income due to injury recovery absence, and loss of promotion opportunity, may in turn influence an underreporting culture.

Based on the unique knowledge, practitioner experience and evidence emerging from this study, it is now posited that evidence of a socio-cultural influence on injury reporting may exist in the occurrence of reported injury proximal to the change of shift (see Section 4.3.3). This position is influenced by results of analysis of temporal preconditions which reveal evidence that the majority (64%) of exceptional violations occurred proximal to the conclusion of a shift.

7.2.2 Injured Party (IP) Experiences.

The study of IP experiences was designed to examine the environmental and contextual characteristics of the ‘moment-of-choice’ of a cohort of 93 participants identified in the data capture study that had experienced the deficit outcome of injury. Several aspects of this study were designed to triangulate the methodological approach of the research. It would also inform the development of an FRS sector specific variant of the HFACS, and possible development of what this discussion now describes as an FRS HF analysis framework (HFAF). However, as explained in Section 6.5 above, readers should be mindful of the default of the analysis process that influenced this summary which originally declared to be one of thematic analysis but was by default more aligned to content analysis.

Just as discussion of the data capture study has raised concern about competence and culture, the analysis of IP experiences not only provided additional evidence of their influence but also added the role of emotional influences to the discussion of IP judgement and choice. The start point of discussion of IP experiences considers an important, unexpected and influential finding of the chosen research approach, that of risk aversion.

The first experience of what could arguably be described as risk aversion occurred close to the completion of the data capture exercise of Study 1. A presentation of interim findings was given to a group of FRS strategic managers responsible for national Health and Safety policy of the Chief Fire Officers Association (CFOA). Discussion explained how the data analysis may reveal a link between fatigue and reported firefighter injury.

Representing one region of the UK one of the attending strategic managers raised concern that the existence of such evidence may cause compromise to planned reductions in establishment levels and introduction of shift patterns involving longer hours of work. In response it was explained that scientific evidence and peer reviewed research has long established links between hours of work and fatigue, and the effects of fatigue on decision-making. Several days after the meeting several FRSs of the corresponding UK region withdrew from the study.

A second example of FRS risk aversion emerged when discussing participation in the IP experiences of Study 3 with one of the FRSs that originally participated in the data capture study. The FRS in question first raised concern about the costs involved in bringing their participants to their Headquarters whilst on-duty and making an officer and room available for interviews.

At a subsequent meeting with a representative gatekeeper of the FRS, influenced by the principles of conducting 'sensitive' interviews (Elmir et al 2011), the importance that a private environment would have for participants was emphasised. It was explained that to reduce the likelihood of vulnerability participants would be given a choice of venue for interviews where they felt they would be comfortably able to participate. It was also explained that this was likely to exclude FRS premises and any meeting venues would be arranged without cost to the relevant FRS or the participant.

Emphasis was also placed on the research design meeting the ethical requirements of Coventry University and the British Psychological Society. It was explained that participation would be voluntary, entirely anonymous and any information provided by individual participants would not be disclosed to the employing FRS. It was also intended that the gatekeeper meetings would establish the best means of contacting the yet anonymous IPs to inform them of the research project and seek their participation in the study. The representative gatekeeper of the FRS stated that if one of his officers could not be present at the interviews, none of his identified IPs would be participating. This decision was later confirmed via email.

Despite the non-representative nature of the participants of this study (described in Section 3.4.3 and Chapter 6 above) the findings continue to triangulate aspects of both Study 1 and Study 2 and add evidence of the prominence of decision-based and skill-based errors and their influence at the 'moment-of-choice'. The findings also add emphasis to the need for improved understanding of the factors influencing the critical decision-making competences of firefighters. Chapter 6 above explains how the probe questions of the Critical Decision Method (CDM) (Klein, Calderwood and McGregor, 1989), provided the main content of the online questionnaire and enabled scrutiny of the key components of competence (knowledge, skill, understanding and experience) applied by IPs prior to, and during a deficit outcome activity.

A key finding of this study was that amongst the participants, 15 held the role of firefighter, more than half (*n*9) indicated that they did not have the required knowledge and skill for their decisions and actions. Their responses also provide evidence that substantiate the argument that critical high risk – high benefit decisions are not exclusive to the domain of those incident supervisors and commanders who unlike firefighters, must demonstrate and maintain competence to undertake the judgement and decision-making demands of incident command.

Using length of service as an indicator of experience, regardless of role, 20 participants of the study exceeded the five-year competence threshold applied to this research (M12.1, SD7.1), (see Section 4.3.2). Examining the components of experience and skill, it was found that the prevalence of skill-based errors in this study would support the concern of Lamb et al (2014) for the effect of skill fade but on this occasion, affecting the 'moment-of-choice' of firefighters. In addition, the influence of decision-based errors once again raises questions about the acquisition, development, and maintenance of their critical decision-making skill and competence.

The literature review of the FRS error management context (see Section 2.8) also explains how psychological precursors can impact the ‘moment-of-choice’. It is this assertion that informs the argument that the most influential of such preconditions is the emotional stressor of ‘Persons Reported’ (PR). In their Striking the Balance statement, the Health and Safety Executive (HSE) recognises that firefighters must make decisions in sometimes emotionally charged situations (HSE 2010).

In the researcher’s experience, the expression PR increases the intensity of a critical event and can invoke an emotional response in those responding. The PR environment is often time constrained due to victim survival and fear of the consequences of erroneous decision-making acts as an additional cognitive stressor (Rahman 2007). Rahman describes how *“information processing in this setting is vastly different from the sterile, affect-free environment assumed by the standard HF information processing models,”* and argues that human performance under these conditions has not been ‘articulated’ well by researchers of the HF paradigm (Rahman 2007:275). The introspective study of injured party experiences included ten cases where victims were involved, eight make explicit reference to PR, five of which involve the ‘moment-of-choice’ of firefighters. More than a decade after Rahman made this assertion, literature review reported extremely limited evidence of academic understanding of the emotional complexities of decision-making in a fire service context (Rhys-Evans, 2019).

A second objective of the study analysing IP experiences was to determine the degree of risk criticality influencing the ‘moment-of-choice’ by comparing the environmental and contextual characteristics with the definition of critical activity used in this research: “*circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome”.* Implicit in this definition is that there has been an assessment of risk-v-benefit.

The ability to recognise and perceive risk is an important part of the mental modelling or cognitive process. The outcome of which is essential to understanding and projecting the possible future outcomes of choice (Endsley 1995, Endsley and Jones 2012). The ability to be decisive about hazards, and perceive risk is inextricably linked to behaviour developed with experience. A key finding that emerged from the analysis of IP experiences was that several (*n*6) participants referred to using the decision-making heuristic - Dynamic Risk Assessment (DRA). Some (*n*5) also described using the Decision Control Process (DCP) (Cohen-Hatton, Butler and Honey 2015, NOG 2021c), at their 'moment-of-choice'. Despite which they still experienced the deficit outcome of injury which DRA is designed to at least reduce, or at best prevent.

Review of the error management context of the FRS (see Section 2.8) identified that the FRS has what is described as a Firefighter Safety Maxim. The maxim states that *"Activities that present a high risk to safety are limited to those that have the potential to save life",* (NOG 2021g). In addition, National Operational Guidance (NOG) sets the expectation that when dealing with PR firefighters will accept a higher level of personal risk (NOG 2021g). The definition of critical activity established by this research embraces this expectation and the maxim has a PR bias.

The Fire and Rescue Authorities Health, safety and welfare framework for the operational environment (DCLG 2013), introduced the concept of Individual Risk Assessment (IRA). Another finding that emerged from the study of IP experiences was that none of the firefighters participating in the study referred to this contemporary process. IRA was specifically developed by a national group of subject matter experts in recognition of concern over the effect of reduced frequency of context relevant experience and the existence of 'skill-fade'. IRA is designed to encourage firefighters to seek help with decision-making when the decision they face is *“not within* [their] *range of skill or experience”* (DCLG 2013:60). Lack of participant reference to IRA would once again bring attention to FRS arrangements for knowledge acquisition, and the maintenance and assessment of competence of firefighters.

Okoli asserts that *“… the ability to effectively conduct dynamic risk assessment on the fireground lies in utilising existing knowledge, which is largely rooted in experience”* (Okoli et al 2016:19), and further argues that when utilising knowledge gained through experience, experienced decision-makers employ intuitive decision-making as a default strategy (Okoli and Watt, 2018). The position of NOG on intuitive decision-making is dichotomous. In one instance, suggesting that it is a negative influence NOG warns that intuition is an errant process and describes it as a decision trap (NOG 2021b, 2021e). However, NOG also describes intuitive decision-making as a greatly used skill. (NOG 2021i). The analysis of IP experiences of Study 3 included evidence from 15 participants who indicated that the ‘moment-of-choice’ resulting in their deficit outcome of injury was intuitive and made instantaneously.

Adding yet further substance to the experience and competence discussion emerging from these findings, the literature review also objectively associated intuitive decision-making with ‘Persons Reported’ (PR) explaining how in circumstances of PR, when life is immediately at risk, decisions can be intuitive and rapid (Cohen-Hatton & Honey 2015; NOG 2021b). Instinctive reactions or ‘gut feelings’ are also associated with the emotional influences of PR (Close 2005). Describing the influence of ‘gut feelings’ on decision-making, Klein posits that they are *“a natural and direct outgrowth of experience”* (Klein 2004: Hiv).

7.3 Discussion of findings arising from the Human Factors study and the use of the Human Factors Analysis and Classification System.

In response to the second research objective, to determine if a sector specific HF analysis tool could be developed for the FRS that could be used to better understand the HF of accident causation, the HF study had two secondary objectives. Firstly, using the Weigmann and Shappell (2003) Human Factors Analysis and Classification System (HFACS) (see Figure 5.1), the study first set out to examine the extent to which the coding judgements of a sample of the participant FRS managers of the data capture study could be considered reliable when applied individually to the same events. The second objective was to adapt the HFACS category descriptors to a more recognisable FRS lexicon with view to developing a sector specific variant of the HFACS (UKFire-HFACS). This would determine the suitability of a UKFire-HFACS variant for improving analysis and understanding of the HF of accident causation in the emergency response domain of the FRS. A UKFire-HFACS could then be used to inform targeted intervention strategies and contribute to a reduction of reported operational injury.

Accident causation analyses models that explore HFs are not entirely unknown to FRS managers. However, an analysis tool such as the HFAF that is specifically designed to explore HF before and during and after the ‘moment-of-choice’, that uses the lexicon of the FRS is an unfamiliar concept and of great value to FRSs when meeting the expectations of NOG for examining ‘the impact of human factors on operational outcomes’ (NOG 2021k).

For Study 2 seven coders who had also participated in the data capture study used the HFACS taxonomy for the first time. Each of the participants were trained and qualified in accident investigation. A finding of this study was that transposing their knowledge to the HFACS taxonomy was greatly assisted by the concept of ‘error typing’ and the use of the Active Error Descriptors (AEDs) of the first study. The design of AEDs replicated and assisted with the examination of the Unsafe Act(s) of the accident-causing sequence that make up the first level of the HFACS.

To assist participant understanding, beta testing was conducted on the guidance and supporting briefing documents to be used with the first case study to moderate and amend the aviation bias of the original HFACS taxonomy. Without prompting, the beta testers offered alternative category descriptors to better match the lexicon of the FRS. These were considered on completion of the first case study when the HFACS taxonomy was moderated to ensure category and sub-category labels and their associated descriptors were more recognisable and applicable to the FRS participants (see Table 5.3).

Two case studies were used in the coding process. The first was based on the FRS and Fire Brigades Union (FBU) reports published following investigations into the deaths of three Firefighters and a Watch Manager at a warehouse fire in Atherstone-on-Stour, Warwickshire in 2007 (Fire Brigades Union 2014, Warwickshire FRS 2016). The second case study was based on similar reports published following investigations into the death of a Firefighter in a fire at an Edinburgh Bar in 2009 (Fire Brigades Union 2017, Scottish FRS 2016). In each case, the FRS reports included a Sequential Timed Events Plot (STEP) which greatly assisted in understanding the sequence, context and influence of critical choices.

A finding important to the development of a UKFire-HFACS variant was the challenge participants encountered when attempting to make code selections for the higher level HFACS category of the first case study (see Table 5.4). Designed to examine preconditions arising from Organisational Influences, this category includes the examination of context relating to strategic decisions, such as budget provision and procurement of appliances and equipment, context unknown to the participants. It was consequently decided to exclude this category from the second case study.

As described in Section 5.3 above the Krippendorff ‘s Alpha (Kα) diagnostic was used to test reliability of individual coder selections. Analysis revealed that the initial application of the HFACS to Case Study 1 (CS1) yielded unreliable results (see Table 5.4). This was also true of the FRS sector modified variant used in Case Study 2 (CS2) (see Table 5.5). Influenced by the research of Olsen and Shorrock (2010), percentage agreement was also applied to the results of this study and used as a comparator with the Kα results. This too yielded unreliable results for each case study. However, the important finding of examining coder agreement was that although they failed to meet the reliability threshold of each diagnostic (Kα = 0.60 – 0.80, percentage = 70%), there was evidence of an improved level of agreement when using the modified HFACS variant in the second case study.

At this stage it was also found that the accident investigation model that participants were familiar with confounded results. Three participants had been trained to use a specific model and their results demonstrated a highly reliable percentage of agreement. In making comparison, it was found that the remaining four participants were trained in the use of entirely differing models. When treated as a group, they too demonstrated similar reliable levels of agreement. This separate investigation model analysis also revealed that the percentage agreement results for each case study were above the acceptable level of reliability (70%), (see Table 5.6). No further research or analysis was conducted to determine the cause of this anomaly.

The chosen methodology was not without its limitations. The section that now follows offers discussion on the limitations arising from these findings and the approach taken in developing the methodology described in Chapter 3 and in the analysis of the results reported in Chapters 4 – 6 above.

7.4 Limitations of the research design and approach.

Several limitations were experienced in the design and conduct of each of the three studies described in the methodology of Chapter 3 and the subsequent specific study chapters above. The structure of the following discussion first identifies limitations under the generic headings of Methodological and Socio-Cultural limitations before describing the specific nature of the issue under discussion. Where and how the issues impact the research journey are then considered before suggesting how future research may overcome the limitations.

7.4.1 Methodological Limitations.

Data Capture Study (Study 1, Chapter 4).

Research Question 2.

Limitation:

The data capture study did not consider what, if any, critical judgement and decision-making training is given to the injured parties on which the data is based.

Impact:

The thesis argues that firefighters do not get the same level of training in critical judgement and decision-making as those supervisors and managers who are required to demonstrate competence for their role as Incident Commanders (ICs). The data capture analysis reveals that 31% of the injury cases provided by the participating FRSs resulted from decision-based errors. There would have been some value in inviting participating FRSs to explain/describe what, if any, critical judgement and decision-making training they provide to their operational staff in the role of firefighter. The provision of training is an important contextual pre-condition and its inclusion in a similar data capture study would expose the adequacy of training arising from a) the IP not having been adequately trained or, b) the IP not applying the critical judgement and decision-making training that has been provided to meet such an expectation.

Future Research Design:

Fundamental to understanding if an IP was adequately prepared for making critical judgements and decisions, consideration should be given to including a pre-participation question set designed to explore FRS arrangements for critical decision-making knowledge acquisition and assessment for those in the role of firefighter. An important caveat is that the definition of criticality applied in the research is aligned to the process of risk assessment which should be considered when constructing a pre-participation question set. Thought should be given to the provision of training that goes beyond knowledge acquisition relevant to the individual and dynamic risk assessment processes.

Future studies should also be mindful of the experience of FRS risk aversion during the data capture exercise and anticipate that participating FRSs may adopt a positive ‘reputation’ bias in their responses. The limiting effect of risk aversion is further discussed in Socio-Cultural limitations below.

Human Factors Analysis (Study 2, Chapter 5).

Research Question 3.

Limitation:

Researcher and participant familiarity with the Human Factors Analysis and Classification System (HFACS) used in the HF analysis of Study 2.

Impact:

Results of analysis of coder agreement using the Krippendorff Alpha diagnostic (Ka) were found to be unreliable for both case studies. Allowing for chance agreement, Ka tests the degree or extent of agreement between coders evaluating given units of categorisation. Results are reliable if they reach or exceed a factor of 0.80; and acceptable between 0.67 and 0.60. Any value below this represents low reliability. None of the results of the case studies reached this level.

Participant knowledge and experience of applying the HFACS was based entirely on guidance provided by the researcher. That guidance was based on practitioner guidance published by the developers of the HFACS themselves (Weigmann and Shappell, 2003). Designed for investigation practitioners such as the participants of the HF study, the book provides several worked examples of how HFACS was designed and used by its developers to *"... explain the human and causal factors associated with actual aviation accidents"* (Weigmann and Shappell, 2003: xiv). Despite the case study content being condensed for inclusion in the participants guidance pack (Appendices 2, 3 & 4) the resulting narratives contained evidence of wide-ranging erroneous activity at all role levels.

Future Research Design:

For continued development of a UKFire-HFACS, a training model based on participant training and familiarisation using FRS examples should be considered by developers and researchers. Guidance should be designed on the principal of drawing participants together as a forum, include worked examples of typical sector case studies, followed by discussion and reconciliation of judgements. This solution supports the findings of Olsen and Shorrock (2010), and Olsen and Williamson (2015 and 2017) that coders rarely have any training in the use of an incident coding system such as the HFACS. However, to develop such a training approach will require both strategic and financial support. Section 7.5 below further discusses the role of the National Fire Chiefs Council in any future developments.

Human Factors Analysis (Study 2, Chapter 5).

Research Question 3 (and relevant to RQ1).

Limitation:

Further relevant to participant guidance in the use of the HFACS was the issue of plurality in the applicability of Active Error Descriptors (AEDs).

Impact:

Plurality of choice holds the potential to confuse coders when making an accurate judgement impacting coder agreement. The potential for a ‘sequence’ of active error where a decision-based error could influence the selection of an item of equipment not designed for use in a particular task was raised by participants. Not only would this represent a type of violation but conversely if the correct equipment was used incorrectly this may also represent a skill-based error. In a similar way, perception error from a lack of complete situation awareness could result in a flawed decision which could also then represent a decision-based error.

The influence of plurality in the 417 cases of Study 1 is less consequential to its influence on the reliability of coder selections when using only two case studies as in Study 2. Therefore, it is important to address the issue of plurality in any future development of a sector specific variant of the HFACS.

Future Research Design:

To reduce plurality of meaning future development of participant training in the use of a UKFire-HFACS should ensure guidance offers clearer definition of any descriptive nanocodes. Reliability will also be improved using ‘decision-flow diagrams’ designed to avoid plurality and ensure exclusivity from similar codes.

Injured Party Experiences (Study 3, Chapter 6).

Research Questions 1 and 2.

Limitation:

The inability to conduct semi-structured interviews with a sample of the 93 Injured Parties (IPs) identified in the data capture study (Study 1) weakened the opportunity to effectively triangulate all three studies.

Impact:

Influenced by McGuirk and O’Neill (2016) who posit that interviewing participants is an effective method of probing personal accounts and exposing the incentives, stimuli, and goals behind human endeavour; Study 3 was designed around the conduct of semi-structured interviews. Of the original 18 FRSs participating in Study 1, only 13 agreed to continue to support the human factors analysis of firefighter injury and participate in this final study. Although, one later withdrew (see risk aversion limitation discussion below). As described above, the final outcome of the IP identification and contact process resulted in only two participants agreeing to interviews (see Section 3.4.3).

On the use of questionnaires literature review revealed how they are equally as effective for discovering conformity and divergence, identifying events and patterns, and gathering data on lived experiences (McGuirk and O'Neill 2016). Consequently, rather than set aside the study, obtaining IP interview evidence was substituted with an online survey questionnaire. Whilst a purposeful approach was taken in identifying the original population of 93 potential participants, the 23 participants of a substitute online questionnaire were neither generalisable or representative of the data capture study.

Future Research Design:

The strength and importance of gathering IP lived experiences should not be underestimated. However, future research should consider the influence of the hierarchical structures and trust relationships in both the cultural and social communities of firefighters and their supervisors and managers. This may be overcome by gaining the endorsement of the strategic managers of the FRS. Section 7.5 below discusses the role of the National Fire Chiefs Council in any future research or development of an HFAF.

Injured Party Experiences (Study 3, Chapter 6).

Research Questions 1 and 2.

Limitation:

The construction and use of the online survey questionnaire.

Impact:

Given the sensitive nature of some of the events the participating IPs would be reflecting upon and the potential for written narrative responses to vary in length and quality, it was decided to set the need for detailed incident description aside. In order to elicit some incident description, a context question asked IPs to briefly describe what they were doing at the time of their injury. More informative narrative responses than those given were anticipated which emphasises the importance of study design being able to maximise opportunities for detailed and insightful accounts of experience.

The original semi-structured interview framework was to be based on the Critical Decision Method (CDM) probe questions used by Salmon et al (2011) in their injury case study. They advise researchers using the CDM to follow a generic procedure which includes compiling a sequential representation of the incident and the significant events. As originally intended, the environment of a semi-structured interview would have prompted an interviewer to make a more detailed and wider exploration of the participant experience and processes of decision and choice.

The substitute questionnaire included 24 original CDM probe questions the majority required binary Y/N responses. To help enrich the contextual picture for more useful analysis and understanding of the participating IPs' 'moment-of-choice', it became necessary to include supplementary questions to direct participants in providing some aspects of this missing narrative. The missing context of these probe questions highlights the limitations of the survey questionnaire where an IP narrative that provides a sequential representation of the incident and any significant events is absent.

Future Research Design:

Wherever possible, researchers should elicit the lived experience of IPs using semi-structured interviews. Where this is not considered possible, thought should be given to the formulation of questions designed to provide a sequential representation of the IPs involvement in incident activities prior to and at the ‘moment-of-choice’ that resulted in the unintended outcome(s). In doing so, the structure of questions should direct participants to the importance of giving a more complete narrative response. It would also be important to broker the support of FRSs. Not only in gaining access to their IPs but also understanding of the ethical requirements of confidentiality.

7.4.2 Socio Cultural Limitations.

Human Factors Analysis (Study 2, Chapter 5).

Research Question 3.

Limitation:

The HFACS case study events involved Firefighter fatalities and were not typical of those that the participating managers were empirically familiar with such as those of the data capture study.

Impact:

Although the deficit outcome of a ‘moment-of-choice’ should be treated with similar importance. The case studies used in Study 2 involved significant, and widely publicised fatal outcomes. Participant analysis was conducted in isolation and open to esoteric influence based on FRS custom and practice and any influence the case studies may already have had on practices. The outcomes of the 417 cases provided for the data capture study where participants were familiarised with the process of ‘error typing’ were much less severe, the majority (*n*286), not involving time loss injury.

Future Research Design:

Reconciliation of this limitation is closely associated with the impact of training and familiarisation discussed above. In circumstances where research replicates the approach taken in this study, case study events used to validate coder agreement should be more typical of the injury events the participating FRS managers are likely to deal with. An important caveat to this criterion would be to ensure case studies are not taken from the FRSs of the participating managers.

Data Capture Study (Study 1, Chapter 4).

Research Questions 1 and 2.

Limitation:

The burden of work imposed on FRS managers collating data not normally included in the administration of their FRS injury reporting processes.

Impact:

As accessibility to the requested data became more remote from the ownership of the role and accessibility of the participating manager, the provision of data diminished affecting generalisability of results particularly those relating to environmental (see Table 4.9) and contextual (see Table 4.11) preconditions. Chapter 3 explains how the final analysis was conducted on data provided by only 18 of the 46 English FRSs (see risk aversion discussion below), the participating managers were asked for 25 items of data in five sub-sets (see Appendix 8). Based on practical experience and knowledge, all the participating managers were guided to take a gradual approach and seek to capture the requested data at the same time they were administering individual accident and injury reports. Most instead chose to wait until the data gathering year had concluded and re-visit all their injury case reports. This created a self-imposed burden on participants for data search and collection and resulted in several of the data sets being incomplete. Secondly, an offer to physically assist was also made. Only one of the participating managers dealt with data collection sequentially and none accepted the offer of physical help.

Future Research Design:

On reflection more emphasis should have been placed on the burden that data capture may impose on participants. Any future research involving data capture of this extent should be explicit in describing the value of the evidence being provided to understanding the influence of HF, and the challenge that data capture may impose and the importance of collating the data gradually as injury reports are administered. Initial contact with FRS gatekeepers should be clear in explaining the additional workload that may be experienced by the data gathering process. There would be great value in arranging pre-participation discussion and briefing where the research experience can be discussed with those managers tasked by an FRS gatekeeper to provide the requested data.

Human Factors Analysis (Study 2, Chapter 5).

Research Question 3.

Limitation:

Using the top tier level of the HFACS - Organisational Influences.

Impact:

For the participants of Study 2, the top tier challenges them to analyse the influence of strategic decision making and corporate responsibility relating to resource management, organisational climate and processes involving budget provision, training and procurement of appliances and equipment. Participants expressed concern that the case study information was limited in this regard. They also explained how, with any future use of the HFACS, not only would they not have access to such information, but they were also of the opinion that this level of scrutiny would not be accessible to them at their role level.

Future Research Design:

Several changes in FRS governance have created an environment of internal and external scrutiny of FRS performance (see Section 7.6 and Table 7.1below). Not known at the time of writing, it is possible that these measures would better examine organisational influences that can impact firefighter safety. Consequently, a UKFire-HFACS variant that focuses on the human factors influencing unsafe acts, their preconditions and supervisory influences would still be able to signpost the need for scrutiny of organisational influences by a suitably appointed authority. It is probable that subsequent strategic or corporate response would be captured by internal or independent external scrutiny and external inspection arrangements. However, depending on severity of injury, any investigation conducted by the Health and Safety Executive, would include organisational influences on outcomes.

Generic Issue (All studies).

Research Questions 1, 2 and 3.

Limitation:

The influence of risk aversion on FRS participation.

Impact:

It is possible that risk aversion affected participation in several ways during the research.

Data capture Study:

As discussed above (Section 7.2.2), close to the completion of the data capture exercise following a presentation of interim findings concern was raised about the impact of findings on strategic plans to change shift patterns and hours of work of emergency response personnel. The impact of which resulted in several FRSs withdrawing from the research.

Injured Party Experiences (Study 3 Chapter 6):

The FRS research contact letter (Appendix 9) used to request FRS participation and help in contacting potential participants was not explicit in describing arrangements for their IPs to participate in an interview. Section 7.2.2 explains how one FRS withdrew from the research upon learning that participant sensitivity, confidentiality, and anonymity could result in conducting interviews away from FRS premises and participant responses would not be shared with the FRS.

The FRS withdrew on the basis that an officer could not be present at the interviews. Subsequently, only 13 FRSs agreed to participate in Study 3 which reduced the number of participants of the original anticipated cohort of 93 to *n*49. Further risk aversion exercised by participating FRS managers may also have influenced participation. Section 3.4.3 explains how potential participants were anonymous and identified by individual FRS case numbers. This necessitated the need to locate them and provide them with the research and participation details. None of the contents of the participant information and consent letters were shared with the managers involved in contacting IPs. Each letter was uniquely tamper-proof sealed with a label displaying the participant case number allocated by the FRS. The purpose of the seal was explained for the benefit of IPs in their enclosed letter (see Appendix 10). It is not known if a positive 'reputational bias', influenced the willingness of the nominated managers to make IP contact without sight of the contents of the sealed envelopes. Subsequently, only two IPs from the same participating FRS made contact.

Future Research Design:

Any future research should consider the potential impact risk aversion may have on FRS participation and participants sample size. If the anonymous contact process is used this should be explained in initial gatekeeper meetings. Alternatively, participating FRSs could be asked to notify their staff via routine publication that the FRS is participating in the research and that IPs may be contacted by the researcher(s). Researchers should also seek the support of the National Fire Chiefs Council (NFCC) in obtaining the cooperation of the strategic leaders of UK FRSs. The support and endorsement of the representative body for Fire Officers - the Fire Officers Association; for whole-time firefighters - The Fire Brigades Union;

and for Retained (on-call) firefighters – the Fire and Rescue Services Association; also have a role in encouraging participation amongst their members.

As discussed above the methodology and three study approach of this research was not without limitations despite which there are also inherent strengths that should not be overlooked which identify their value and need for further research. The section that now follows considers these strengths which in turn informs the value of future research interest.

7.5 Emergent Strengths of the Research.

Influenced by the reflexive experiences of the research processes this section offers further discussion on what are considered to be strengths of the human factors analysis of firefighter injury. The research was based on a methodology used to examine the human factors of firefighter injury sustained during emergency response operations using a triangulated three-study approach. An analysis of the pre-conditions that influence choice, the application of a human factors analysis system, and the introspective experiences of injured parties were designed to allow the emergent evidence to be validated. Whilst the three-study approach provides the structure for the following discussion they also represent the potential for future development as three component parts of a holistic HFAF for the FRS.

7.5.1 Study 1 Data Capture.

A strong point of this research lies in how literature review revealed little evidence of contemporary peer reviewed research that specifically focuses on the judgements, decisions, and critical choices of those in the role of firefighter. In contrast, that which uses the term firefighter to examine the decision-making of Incident Commanders proliferates, much of which originates in the embryonic growth of the Naturalistic Decision-Making (NDM) paradigm (Butler, Honey and Cohen-Hatton 2019; Klein, Calderwood and Clinton-Cirocco 2010; Okoli et al 2016). No evidence could be found of a descriptive data analysis such as this first study being undertaken by either the strategic managers of the FRS or researchers of the safety or the judgement and decision-making paradigms. Added to which, that the study methodology could be easily replicated adds additional strength.

A particular strength of the methodological approach of Study 1 was the concept of 'error typing' and use of Active Error Descriptors (AEDs). Not only were they effective in identifying and categorising the influence of decision-based; skill-based; or perception-based errors and violations, but they were also compatible with the examination and adaptation of the human factors analysis system that a small cohort of participants used in Study 2. AEDs were also used in the coding and analysis of responses of Study 3.

Important to the aim and objectives of the research the dominance of decision-based errors identified in Study 1 supports the argument that, in a similar way to their supervisors and commanders, firefighters should have to acquire and demonstrate an enhanced level of critical decision-making knowledge, understanding and practice. However, adding strength to the outcomes of the study, the dominance of skill-based errors when compared with length of service of injured parties (M14.55, SD7.8) supports the position of Lamb et al (2014) for the effect of skill fade. This evidence brings attention to the effectiveness of arrangements for the maintenance of competence of firefighters and should be of interest to the strategic leaders of UK FRSs.

An important area for future research lies in the unexpected outcome that emerged late in the compilation of this discussion which revealed evidence that socio-cultural influences could impact the reporting of operational injury. An area not initially considered but supported by the assertion of Pransky et al (1999). Given the FRS commitment to people development (Fire Standards Board 2021a and b, NOG 2021m, NFCC 2021) there is value in pursuing research that either refutes or confirms the existence of injury under reporting.

7.5.2 Study 2 Human factors Analysis.

The development of UKFire-HFACS has great strength. Not only for the contribution such an analysis tool can make to understanding the human factors influencing the 'moment-of-choice' but also the contribution it makes to developing targeted intervention strategies and reducing reported operational injury. Further development in transposing the structures of the emergency response domain of the FRS to the layers of the HFACS taxonomy should be undertaken. Improved coder agreement lies in user training supported by decision flow diagrams and clearer definition of nanocodes to overcome plurality of meaning.

Any future research of UKFIRE-HFACS should also consider the unexpected finding that the accident investigation model participants are familiar with could produce more reliable results (see Table 5.6). However, none of the limitations discussed in Section 7.4 above should be considered barriers to the development of UKFire-HFACS. Despite reliability in coder selections using the Krippendorff Alpha diagnostic and percentage agreement being low, when viewed as a 'pre-post' study experiment, the strengthening of reliability in coder selections when the taxonomy had been revised to a more FRS specific variant would indicate there is great merit in the continued development of a valid and reliable UKFire-HFACS.

7.5.3 Study 3 Injured Party Experiences.

Despite the suboptimal use of an online questionnaire the strength of this study lies in evidence that would suggest there is opportunity for both FRS leaders and researchers to better understand the environmental and contextual characteristics that influence the 'moment-of-choice' of firefighters. A key strength of conducting interviews to examine and analyse injured party experiences is the opportunity it affords to obtain access to the participants subjective natural real-world experience, in an 'own words' description not normally given in a questionnaire response. Knowledge and understanding of the influence of the psychological pre-cursors would be significantly informed by analysis of the introspective experiences of those firefighters who experience the deficit outcome of injury resulting from their own critical decision-making.

Together, the three studies of this research can be viewed as three component parts of an FRS HFAF where initial or foundation data gathering is conducted in a similar way to the error typing process of the data capture study. Also using error typing, the more detailed analysis afforded by HF analysis of Study 2 using a sector specific lexicon creates opportunity for more detailed identification and understanding of the unsafe acts, their preconditions, supervisory influences including incident command structures and processes, and subject to specific FRS governance arrangements, the organisational influences of reported operational injury. Finally, offering the opportunity for more detailed analysis of HF, criticality can be better understood by the analysis of accounts derived from the use of injured party interviews.

Based on the application, analysis, and findings of his three- study design, as a concluding section, discussion now considers where or how an HFAF could be positioned to inform targeted intervention strategies and contribute to a reduction of reported operational injury.

7.6 Application to the Fire and Rescue Service.

Before concluding this chapter, it is important to consider the specific value the research holds for the fire and rescue sector who arguably has the most to gain out of the research journey from design to implementation and analysis of findings.

National FRS governance developments (see table 7.1 below), in the life of this research journey include a new strategy to produce National Operational Guidance (NOG). Commenced in 2012, the original programme had been successful but to be sustainable the programme funding model and programme organisation required substantial review and government intervention which was secured in 2015. In this year a programme to establish a National Operational Learning platform (NOL) was also launched. The programme to create NOG reached its conclusion in 2018. After which the focus was on ensuring relevance, currency, and quality of content. 2018 was also when the NOL platform was formally launched. The discussion of limitations and strengths of the previous section postulates that this research sets the catalyst for the development of a holistic HFAF. If the findings of this research hold such an application to the fire sector or could inform sector developments, it would be guided by NOG and/or NOL.

NOG is primarily directed toward those strategic FRS managers with responsibility for the risk assessed delivery of emergency response operations and those of their officers responsible for writing the policies, procedures and systems of work designed to achieve the safe and effective resolution of incidents. Whilst not specifically directed towards those in the role of firefighter, NOG directs FRS procedure and policy writers to those circumstances that firefighters should be specifically aware of that should be included in their FRS operational procedures. A significant bias of NOG is toward those who will be responsible for all the resources that respond, and the systems of work adopted for the safe resolution of incidents of all/any type – the Incident Commander. The Incident Command guidance does however categorically state that it is essential reading for all *"…operational personnel…"* (NOG 2021 l)

It is important to note that the lexicon of NOG is carefully constructed and follows a positive rather than a negative model. Reflecting the dichotomy of language found in the literature (Dekker 2014, Hollnagel 2015), and avoiding negative reference such as human error, guidance emphasises the product of effective performance and is directed towards a broad spectrum of hazards and control measures that can compromise the safe and effective resolution of incidents of all types. When describing hazards NOG avoids describing failure and the inflection of narrative describing controls is directed toward successful hazard management.

Incident command guidance does include limited discussion of physiological, psychological and human factors that can influence effective performance and command decision making. Reference to human factors is limited and the incident command guidance acknowledges that *"cognitive skills come under the heading of human factors"* and explains how post incident review should take account of *"…the impact of human factors on operational outcomes"* (NOG 2021 k).

NOG reference to reported operational injury is found in guidance relevant to the administration and management of post incident review and injury investigation. It explains how investigations can be compromised and describes how the conduct of or support established for investigations is an effective control measure (NOG 2021 m).

Where injury investigation is concerned, it is not the role of NOG to identify any specific investigation model, product or practice. Therefore, the role of NOG in the application of a HFAF would be generic to FRSs understanding the hazards that could cause compromise to effective reporting and administration of a generic HFAF. Controls that ensure those responsible for its use are competent, understand the hazards, and have access to the appropriate data and information on which it would be based would be emphasised and adequately referenced throughout the relevant narrative. Therefore, it is more likely the outcomes that an HFAF can make to systematically understanding errors more appropriately lies in the role of NOL.

NOL is the conduit used by FRSs to accumulate and share learning experiences arising from accidents in the emergency response domain and preventing their repetition. Integral to NOG, the intention of NOL is to improve firefighter safety across the FRS sector. The principles of NOL meet the foundation of isomorphic learning which asserts that *"…any failure that occurs in one system will have a propensity to recur in another 'like' system for* *similar reasons"* (Toft and Reynolds 2005:27). A good practice guide (NOL 2021) sets out the framework an FRS should establish to ensure organisational (internal) and cross organisational (external) isomorphic learning. In achieving this objective, the guide requires FRSs to establish the role of Single Point of Contact (SPoC).

One of the key functions of the SPoC is to oversee the implementation of change arising from internal and external learning experiences. To do so requires FRS to have systems in place for gathering relevant information and data. The guide also emphasises that those responsible are adequately able to identify where and how their own and other FRSs will be affected by an isomorphic event. In achieving this responsibility there is an expectation that the existing expertise of an FRS health and safety management and administration system will be utilised. This would include the FRS managers normally responsible for the administration and management of injury investigation information and data who formed the cohort of participants of the data capture study of Study 1. That study demonstrated how FRSs maintain a broad spectrum of data that represent the preconditions of accident causation.

As noted in socio-cultural discussion of limitations in section 7.4.2 above, to gather the requested data for many of the participants created a burden of work that impacted the sample size based on accessibility to data. For some participants this burden was more demanding than for others. The analyses of Chapters 4 – 6 above explicate how the exposure to the hazardous conditions of the emergency response domain has a direct relationship with reported injury. The greater the emergency response the higher the numbers of reported injury events to investigate, report and administer. As an example of the additional work data gathering may impose, the number of injury events reported by the 38 non-Metropolitan FRSs of England in the year of the study was 812. Having a much wider area of community risk and operational response, the seven Metropolitan FRSs of England reported a total of 345 injury events (Home Office 2020). Including several

Metropolitan FRSs, the 18 FRSs participating in Study 1 reported 417 injury cases. That with the greatest demand would deal with three every week, and the least no more than one per month.

FRS arrangements for the identification and sharing of isomorphic learning rely on the SPoC function to identify, review and categorise learning opportunities arising from specific activities including those of the FRS managers normally responsible for the administration and management of injury investigation information and data. As previously discussed, it will be in the health and safety arrangements of an FRS that the HF of firefighter injury could initially be captured by an HFAF the outcome of which could then be delivered for review by the SPoC process. SPoC analysis is required to use a traffic light system when categorising isomorphic learning.

At the time of writing, categorisation was designed around four rating triggers. Red and amber represented identified cross organisational learning to be shared across the fire sector. Any organisational learning limited to a specific FRS is categorised as green and blue (for ease of reference the FRS adopted BRAG as the representative acronym). In the case of events rated as red and amber, NOL holds the expectation that they are shared throughout the FRS sector immediately. However, as in the risk aversion experiences discussed above, NOL also recognises that there will be circumstances where an FRS may be ‘cautious’ about sharing information *“…when it may evidence performance that may not reflect good practice*...” (NOL 2021). As in the case of the influence of HF discussed above and reflecting the ‘systems’ view found in the literature, NOL gives greater importance to the ways things are going right (Hollnagel 2014:175, Woods et al 2010). NOL emphasises that its learning focus is on the ‘why and how’ of isomorphic learning (NOL 2021). NOL also sets the expectation that FRSs have robust policies in place to ensure that any necessary changes to policy, training and procedure arising from isomorphic learning are embedded into the systems of work of the emergency response domain.

In October 2021, as part of national FRS governance arrangements the FRS sector adopted a ‘workforce good practice framework’. Designed to enable FRSs to self-assess performance against a performance benchmark the framework includes 10 ‘maturity models’ that enable an FRS to conduct a gap analysis against their current level of performance with a more ‘mature’ target benchmark level (NFCC 2021). In conjunction with this good practice framework, FRS governance arrangements also include the role of the Fire Standards Board which oversees *“…the identification, organisation, development and maintenance of professional standards…”* of English FRSs (Fire Standards Board 2021a).

In a similar way to the workforce good practice framework the professional fire standards of the Fire Standards Board also set a benchmark against which FRSs performance can be measured. There are currently 12 approved professional standards three of which relate to operational response which include a standard for ‘Operational Learning’ published in February 2021. Linked to both NOG and NOL, this standard requires an FRS to have a process that captures learning arising from *“…near miss or accident investigations that may be relevant to operational response.”* (Fire Standards Board 2021b)

Her Majesty’s Inspectorate of Constabulary and Fire & Rescue Services (HMICFRS), now conducts and publicly reports the results of a regular programme of FRS performance inspections. The performance measures published in the good practice framework, an operational learning standard published by the Fire Standards Board and additional FRS maturity self-assessment measures are now closely scrutinised. The product of this research establishes the potential for HFAF to be applied as a periodic health check or performance measure that coincides with the FRS inspection cycle of the HMICFRS.

To conclude this chapter, it is now argued that the effect of isomorphic learning arising from the application of an FRS HFAF would be to provide measurable evidence of performance.

Evidence that could make a significant contribution to meeting the performance measures of the Fire Standards Board. It could also demonstrate evidence of workforce good practice across several maturity models in particular, those demonstrating that an FRS is a 'Learning Organisation'. More importantly, evidence emerging from an HFAF would inform targeted FRS intervention strategies that improve error management and contribute to injury reduction in the Fire and Rescue Service (FRS).

Table 7.1 Depicting FRS governance arrangements occurring in the life of the research.

	Research Activity	Changes affecting English FRS governance arrangements
2014	Research Commenced	Original National Operational Guidance Programme review pending.
2015	Study 1 Commenced	Future of National Operational Guidance secured. National Operational Learning Programme developments commence. Government responsibility for the FRS moved from Department of Communities and Local Government to the Home Office.
2016	Study 2 Commenced	Home Secretary announces the launch of the fire reform programme.
2017	Study 3 Commenced	Home Secretary announces the formation of Her Majesty's Inspectorate of Constabulary and Fire & Rescue Services (HMICFRS). National Fire Chiefs Council established. Responsibilities include development and adoption of Operational Standards.
2018	Research Suspended.	National Operational Guidance assembly completed. Development and maintenance commence. Government announces formation of a Fire Standards Board. First FRS inspection programme published by HMICFRS. National Operational Learning platform formally launched.
2019	Study 3 re-commenced.	Fire Standards Board announced consultation on first fire standard.
2020	Study 3 Concluded.	First Fire Standard published (Emergency Response Driving).
2021	All Research Concluded (writing commenced).	HMICFRS published first State of Fire report. Fire Standards Board publishes Operational Learning Fire Standard. FRS publishes a National Workforce Good Practice Guide. National Operational Learning Good Practice guide also published.

8. CONCLUSION.

This human factors analysis of firefighter injury sustained during emergency response operations addresses three research questions:

Research Question 1 (RQ1) –

How effective is the FRS at gathering, analysing, and understanding the pre-conditions and human factors of accident causation.

Research Question 2 (RQ2) –

When working without the oversight of a supervisor or commander firefighters may be called upon to make a ‘critical decision’. When doing so, to what extent do they experience the deficit outcome of injury, and what type of active error is injury more likely to result from.

Research Question 3 (RQ3) –

When developing targeted intervention strategies, how effective would a sector specific analysis tool be in supporting the FRS to better understand the active errors, their pre-conditions, and the supervisory and organisational influences of accident causation.

This research has resulted in what can be described as the first examination of the influence of human factors (HF) on the critical choices of firefighters (RQ2) as opposed to the judgements, decisions, and choices of their supervisors and commanders.

The findings substantiate the argument that critical high risk – high benefit decisions are not exclusive to the domain of fireground commanders. Yet, for many years, the direction taken by researchers of the Naturalistic Decision Making (NDM) paradigm heavily focusses on the judgements, decisions, and choices of those who perform the role of fireground incident commanders.

Whether a novice or experienced in command decision making, the incident commander of the Fire and Rescue Service (FRS) has been selected for, trained, assessed, and had to demonstrate competence at regular intervals to exercise command judgments and decision making in the emergency response domain. Whilst acknowledging that it is relevant to all who may be called upon to make tactical decisions, the national operational guidance on which their competence is based is heavily biased to the role of the incident commander.

The same cannot be said of the critical decision making preparedness of the firefighter who will be tasked by them to achieve the objectives of their tactical plan. Yet they are likely to be the first to encounter and react to the unknown, sometimes unexpected incident developments that an incident commander is not sighted on. That researchers of the NDM paradigm have not paid the same attention to the critical decision making of those in the role of firefighter constitutes a gap in knowledge, a gap this research exposes and seeks to close.

In exploring RQ1and based on data all FRSs hold, it has been established that experienced firefighters are more likely to suffer the deficit outcome of choice and that the frequency of reporting injury increases as they become more experienced. Using error typing for the first time it was possible to establish that skill-based and decision-based errors are more likely to influence the deficit outcome of the ‘moment-of-choice’ of the experienced firefighter. Consequently, worthy of closer scrutiny by both academics and practitioners this research:

- ◊ exposes weakness in the judgement and decision-making of firefighters that results in their injury;
- ◊ provides evidence that substantiates the existence and influence of skill fade affecting their ‘moment-of-choice’;
- ◊ brings FRS arrangements for the maintenance of competence worthy of scrutiny; and
- ◊ argues that firefighters should be better prepared for and demonstrate competence in critical decision-making before being called upon to do so.

Since conducting this initial study there have been many developments in strategic, operational, and tactical management arrangements of the FRS which could impact on reported injury. The most recent FRS report of operational injury data (Home Office 2021) indicates a reduction in reported operational injury over the last two years.

This thesis argues that there is an inverse relationship between exposure and injury and as reported injury has reduced (≈10%), so too has exposure to the challenges and demands of firefighting in the emergency response domain (≈7%). This means it is not possible for the FRS to categorically state that the reduction of injury is a direct consequence of improvements affecting safety in the emergency response domain.

To validate the efficacy and implications of this research for injury reduction in the emergency response domain, it is recommended that, based on experience gained from this research, the data capture study is repeated, and the outcomes subjected to scientific peer review.

Before the initial data capture exercise of this study, it was difficult and therefore uncommon for the FRS either individually or collectively to analyse the influence of human factors in reported injury causation. However, the national FRS guidance overtly states that the command skills of an Incident Commander (IC) *"come under the heading of human factors",* that ICs should be supported to reduce the *"risk of human factors affecting safety",* and as part of the normal process of post incident review the use of command skills by ICs should be examined *"to highlight the impact of human factors on operational outcomes"* (NOG 2021k).

The data capture process of this research has presented evidence that by adopting an 'error typing' model it is possible for individual FRSs to improve understanding of those human factors that in some way influence judgement and choice.

It should be emphasised that it is not the intention to label the erroneous outcome of judgement and choice negatively by association with human error. As in the title of this thesis the influencing factors are clearly and positively labelled as the Human Factors of Firefighter Injury. What is of greater importance is that the data capture analysis of Study 1 does bring attention to FRS practices that should be closer examined in order to establish suitable interventions to reduce their negative influence on firefighter safety.

Further academic and practitioner development of the error typing would serve to improve academic understanding of the psychological precursors affecting the critical decision making of firefighters. This would also enable the FRS to adopt a more focused national operational learning and intervention strategy based on peer reviewed scientific evidence.

By adopting the ethos of criticality and the definition of critical activity in decision making - *“circumstances where the risk-v-benefit balance required the Injured Party (IP) to undertake a high-risk task activity with a high benefit outcome”;* error typing is able to identify injured parties (IPs) that experienced the deficit outcome of their ‘moment-of-choice’ when exercising a critical decision. This was the group that were to form the locus of interest of the final study. But an alternative approach had to be taken and a substitute sample of injury cases formed the analysis of injured party experiences. The current findings, although aligned to content analysis, revealed the existence of socio-cultural influences that may influence the under reporting of injury and the risk taking behaviour of firefighters at their ‘moment-of-choice’. More importantly, supporting the views of Rahman (2009) and Rhys-Evans (2019) not enough is known about the emotional influences that impinge on the critical decision making of firefighters and this research exposes the need for better understanding of the emotional stressor of ‘Persons Reported’.

Therefore, it is recommended that the FRS should undertake research to confirm or refute the existence of socio-cultural influences on the reporting of injury and risk taking behaviour of injured parties. In addition, the safety science and psychology disciplines should undertake more detailed and specific peer reviewed scrutiny of the affect of the emotional stressor 'Persons Reported'.

Between the data capture study and analysis of injured party experiences the potential to develop a sector specific human factors analysis tool was the focus of a second study. Chosen for its compatibility with the error typing technique of the first study, and introduced to the participating FRS managers for the first time, the Human Factors Analysis and Classification System (HFACS) formulated by Weigmann and Shappell (2003) was the chosen analysis tool. The extent to which the judgement and agreements of a small cohort of coders could be considered reliable, and the applicability of a modified and more sector specific variant of the HFACS was also explored.

The limitations of the application of the HFACS to two case studies are discussed in the previous chapter but a human factors analysis using an analysis tool such as the HFACS has the advantage of revealing several 'factors' associated with unsafe acts and their preconditions. So too does it allow analysis of the erroneous influences that supervisors and managers may have on the deficit outcome of a moment-of-choice'.

Reliability in coder selections when analysing the results of two case studies was low and on reflection the use of cases similar to those reported in the data capture of Study 1 may have been more appropriate. Despite which, representing a 'before and after' experiment, the strengthening of reliability in coder selections when the taxonomy had been revised to a more FRS specific variant would indicate there is great merit in the continued development of a valid and reliable FRS variant of the HFACS (UKFire-HFACS). Error management and injury reduction in the emergency response domain of English Fire and Rescue Services would be greatly assisted by the use of such a sector specific analysis tool.

Triangulation of the three studies that comprise this research establishes their compatibility and interdependency. Whilst there is great merit in continuing their development as identified in this concluding chapter, this shouldn't be conducted in isolation. Any future research direction should take account of the strength and value in both academics and practitioners developing these studies as three component parts of a holistic Human Factors analysis framework (HFAF) for the FRS.

However, experience gained whilst undertaking this research has found that whether error typing of the first study is adopted as a continuous process by individual FRSs, or a combined holistic framework is periodically applied for national reporting, it is important that the strategic leaders of the FRS and the various representative bodies endorse and support the participation of FRSs and individuals alike.

The findings of this research indicate strength of continued development of an FRS HF framework which includes UKFire-HFACS lies in the contribution such a framework can make to error management. By informing targeted intervention strategies such a framework would not only lead to a reduction in reported operational injury but also contribute to greater understanding of how a simple but erroneous act can result in injury and why it would make so much sense to those involved at the time.

In closing, it is important to record how the reflexive experience and milieu of this research journey prompted several episodes of personal reflection and sensemaking that resulted in shaping the chosen research journey. The discussion it presents reveals that although the research may have contributed new knowledge and understanding, it only represents a direction of travel and not a destination. The socio-cultural and qualitative research reality it exposes is that the Human Factors analysis of reported Firefighter injury sustained during emergency response operations raises yet more questions.

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Appendix 1

Guidance for application of the Human Factors Analysis and Classification System (HFACS) as provided for participants in Study 2 case studies

FIREFIGHTER INJURY RESEARCH PROJECT Phase 2
Guide to
The Use and Application of a Human Factors Analysis Framework
Applied to
UK Fire and Rescue Service Case Studies

Introduction
You will recall from your participation in the Phase 1 Data Capture study that you were asked to provide an 'Active Error Descriptor' (Item 5.4). This focussed on the first level of the analysis and classification framework you will be using in this exercise. All participating Fire and Rescue Services were asked to make these judgements. The purpose of the Phase 2 study is to use a sample of the Phase 1 participants in what is called an Inter-Rater Reliability test which achieves two main objectives. Firstly, it will serve to validate your Phase 1 Active Error judgements. Secondly, it is designed to compare judgements made in a case study analysis to determine the level of agreement between participants. This would also begin to provide evidence of the suitability of the analysis tool for application in the Fire Service.

Human Factors describe how human performance is influenced by the environment in which people work. It considers the tools and equipment people use, and the people and relationships that influence their performance. The system you will be using has been in use for over 15 years. It takes a multi-level approach to analysis and over time can provide a data set that can lead to error reduction. It has never been applied to error analysis by a UK FRS. Not only will it be strange and initially, possibly difficult to interpret, but so too may many aspects of it be familiar to you.

The judgements you will be asked to make mainly relate to the first three levels of the classification system but all four levels have been included in the exercise. The purpose of this guidance is to help you understand and apply the analysis tool to two UK FRS Case Studies.

This guide provides some helpful background. Along with the accompanying spreadsheet workbook and note pages, it organises your analysis in a logical, step-by-step manner. It is accepted that this guide cannot substitute for formal training in the detailed history, background and application of the model you are using. However, for this stage of Phase 2, it is accepted that participants are trained in accident investigation but will have varying degrees of experience. This makes your review/feedback comments far more important and influential and will of course make a significant contribution to shaping a bespoke UK FRS version that has the potential to:

- Analyse and classify Human Factors influences in accident causation;
- over time, establish a 'predictive' database of Human Factors characteristics; and
- contribute to a reduction in operational injuries.

I'm sure you would argue that ordinarily you would have far more accident investigation evidence on which to base your judgements. However, the purpose of this exercise is to examine the level of agreement on exactly the same information. Whilst reading through, you will realise the guide gets slightly caught between an academic text and a useable tool. I hope you don't find the way the writing style changes frequently between formal/academic language and semi-informal language too distracting.

I sincerely hope you realise the value of this approach to categorising human factors and how, a more detailed analysis of those factors and activities that can be corrected or improved could lead to a consistent approach and national learning.

Background

You will be familiar with James Reason's 'Swiss Cheese' model (SCM) which is about organisational resilience and 'defence in depth' which is another expression you will be familiar with. Figure 1 demonstrates how at the end of a trajectory of accident causation the unsafe acts of individuals can lead to injury causing accidents. The SCM uses slices of Emmental cheese as a metaphor to illustrate how various organisational barriers can be vulnerable to failure and allow an accident causing trajectory.

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Figure 1 Reason's Swiss Cheese Model Source: Douglas Wiegmann and Scott Shappell (2003), adapted from James Reason (1990).

The SCM shows that some of the 'holes' can be pre-existing and may have been dormant for some time. These latent conditions can also be removed in time and space from the accident causing active failures and are known as Latent Failures. Normally, an investigation starts with the immediate actions that lead to an accident. As an organisational accident model, the SCM requires investigation to consider the influence of the latent conditions that allowed the accident causing trajectory.

The analysis and classification system you'll be using was originally developed in response to a call for a reduction in US Military Aviation accidents. Recognising how the limitation of the SCM lay in its failure to *'identify the exact nature of the holes in the cheese',* psychologists Wiegmann and Shappell (2003) produced a framework to be used as an accident investigation and analysis tool. It bridged the gap between theory and practice; identified and classified the human causes of aviation accidents; and was designed to *'define the latent and active failures implicated'* by the SCM. Wiegmann & Shappell referred to the development of their model as "*a means of defining…the holes in the cheese…"* (Wiegmann and Shappell 2003). Known as the

Table 1 Research involving the application of HFACS in domains other than Aviation.

Authors	Domain	Publication Title	Year
Patterson J M, Shappell S A	Mining	Operator error and system deficiencies: Analysis of 508 mining incidents and accidents from Queensland, Australia using HFACS.	2010
Celik, M, Er I D	Shipping	Identifying the Potential Roles of Design-based Failures on Human Errors in Shipboard Operations	2007
Paletz, S B F, Bearman, C, Orasanu, J, Holbrook, J	Social/ Psychological	Socializing the Human Factors Analysis and Classification System: Incorporating Social Psychological Phenomena Into a Human Factors Error Classification System	2009
Diller, T, Helmrich, G, Dunning, S, Cox, S, Buchanan, A, Shappell, S.	Health Care	The Human Factors Analysis Classification System (HFACS) Applied to Health Care	2013
Ryerson, M, Whitlock, C.	Wildland Firefighting	Use of Human Factors Analysis for Wildland Fire Accident Investigations	2005
Hughes, A M, Sonesh, S, Zajac, S, Salas, E.	Emergency Medical	Leveraging HFACS to understand medication error in Emergency Medical Services (EMS): A systematic review.	2013

Know

Human Factors Analysis and Classification System (HFACS) it has been shown to be a comprehensive tool with diagnostic qualities that make it reliable, usable and whilst valid in both Military and Civil aviation, applicable to several other domains (Diller et al 2013), (for examples see Table 1 below). HFACS has also been noted for being organised in an efficient, hierarchical way. One that reduces mental demand on its users (Beaubien, J. M., & Baker, D.P. (2002). HFACS is found to capture the entire range of system errors from those of the operator through to higher levels of management and governance. The data it provides can inform objective data-driven intervention strategies, and track their level of success in achieving accident reduction revealing relative changes in incident and accident data. The quick, user friendly, categorisation scheme has consistently demonstrated acceptable to high levels of inter-rater reliability (Shappell & Wiegmann, 2000; Salmon, Cornelissen & Trotter, 2012) and it is these that the Phase 2 study sets out to test.
Introducing human error classification to the UK FRS for the first time using HFACS this Phase 2 study also creates an opportunity to develop UK FRS specific performance codes. So now let's take a look at the basic levels of HFACS.

<u>HFACS Level 1 – Unsafe Acts</u>

You will already be familiar with the first level from the Phase 1 study previously mentioned. This is how Weigmann and Shappell represent it:

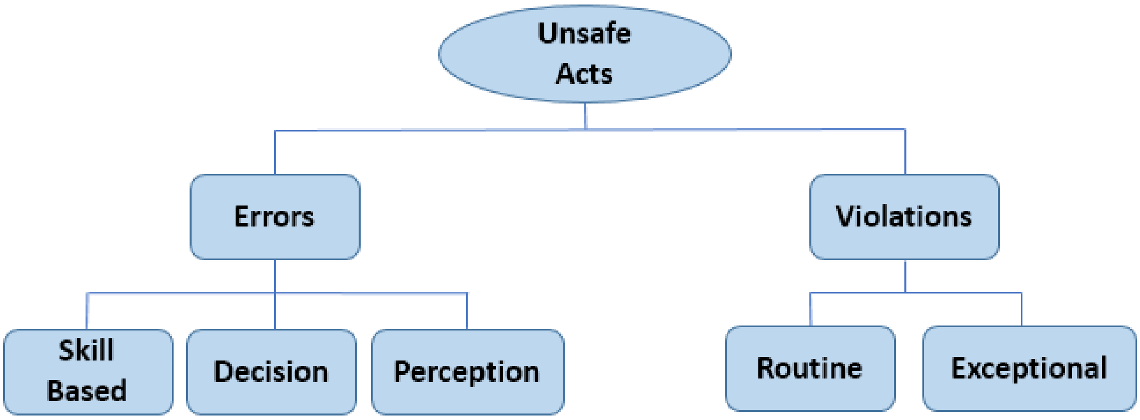

Figure 2 Showing the first level of HFACS. Adapted from Wiegmann & Shappell 2003

Skill Based Errors
Skill based behaviour occurs without conscious thought. It develops with knowledge of the practical application of taught and learned skills. As a result, skill based actions can be particularly vulnerable to failures of attention and/or memory. They are the simple attention failures of highly automatised behaviour. A typical example would be missing an appliance cab step when mounting/dismounting.

Perception Errors
This is about not making sense of the situation, having a perception that differs from reality because of the environment. Not understanding direction when vision is impaired, or where size, shape and dimensions are misjudged in the dark or when in smoke.

Decision Errors

Often referred to as "honest mistakes" decision errors represent intentional behaviour that proceeds as planned but the plan itself is inadequate or inappropriate for the situation. This would include well intended actions but without the appropriate knowledge, or simply arise from a poor choice. Decision errors can be procedural or rule based where error occurs when the situation is not recognised, misdiagnosed or the wrong procedure is applied. They can involve a poor choice when presented with an option. Or they can occur when the situation is not well understood and formal response options are not available, where the invention of a novel solution is required.

Violations
Fortunately, violations occur much less frequently than the errors described above but can result in serious injury. Violations occur when the individual knew what should be done but chose not to comply.

Routine Violations
These tend to be habitual and in some way tolerated by 'blind eye' supervisors or managers. Such as allowing routine violation of driving in excess of the speed limit during non-emergency driving. Simply seen as 'bending the rules' they are allowed by the line of supervision or management where their 'permissive' origins may lie.

Exceptional Violations
These are the 'exceptional' isolated departures from the rules. They are more often than not heinous but should not be considered exceptional because of their extreme nature. They are not typical of the individual responsible for the 'active error'. Typically, when asked, individuals are left without an explanation for exceptional violations. They are often conscious of the possible consequences of their actions.

HFACS Level 2 – Preconditions of Unsafe Acts

When you first glance at the level 2 flow chart below the first thing you'll think is 'how am I supposed to know that'? Please don't be too concerned because for this first exposure to HFACS we'll be adapting some of these categories to the current practices and lexicon of the FRS. What you will see in the Personal Factors group is reference to Crew Resource Management (CRM) which also originated in the aviation sector. CRM is not currently widely known to UK FRSs but has great value in terms of team building, safety culture and behavioural influence. Let's now take a look at the sub-categories of level 2.

Environmental Factors
As you can see these are sub divided into two categories and you will recall the phase 1 study asked for some of this kind of data. First we'll look at the physical environment in which the active error occurs:

Physical
The phase 1 study looked at these from several perspectives, arguably starting with the time of day/night the active error may have occurred as the physical environment differs in conditions of light and dark. But this was also captured separately in Section 3 of Phase 1. It was mainly under the heading of Incident Profile that the majority of the physical environment factors were explored including: 1) incident type; 2) surface conditions; 3) ground conditions; 4) weather conditions; and 5) visibility. Many of these can impact the visual cues and physical demand placed on individuals. Unfortunately, not all the participating FRSs in the Phase 1 study were able to provide this information. Finally, common to all those entering firefighting environments heat can affect decision making.

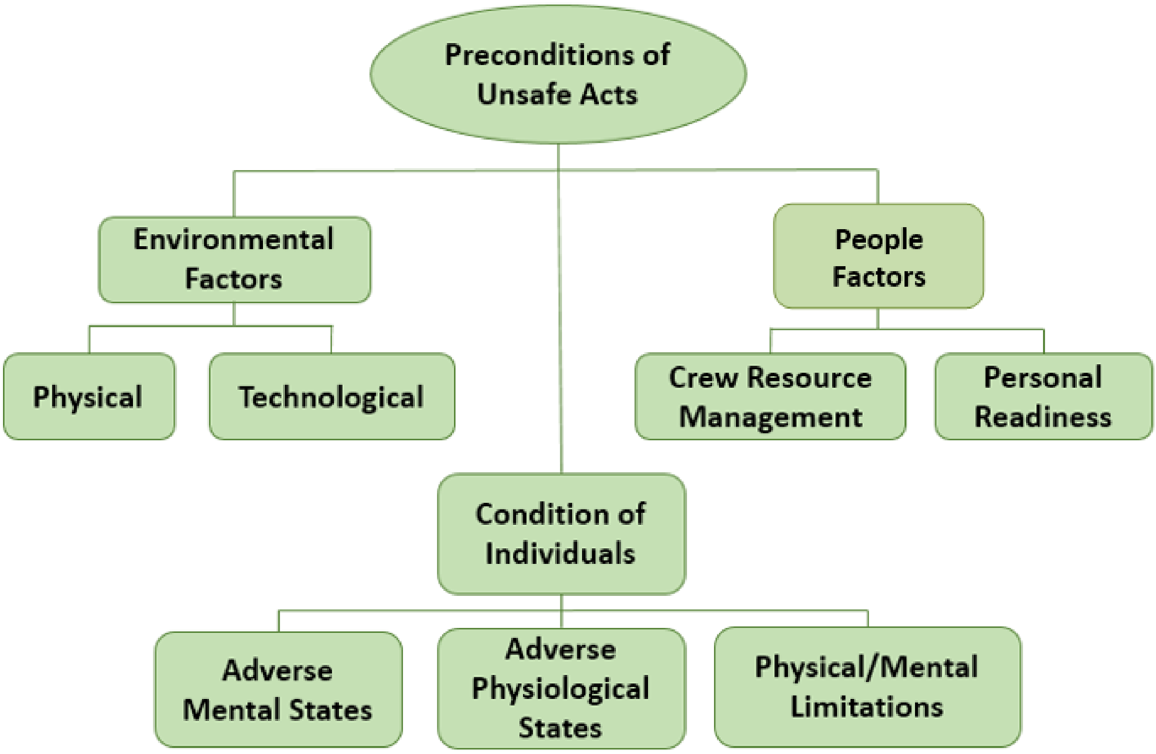

Figure 3 Showing the second level of HFACS. Adapted from Wiegmann & Shappell 2003

Technical
This is much more straightforward and relates to the equipment provided/used at the time the active error occurred but with this sub-category care must be taken not to be influenced by the causes of decision errors described above. This is more about the performance and/or suitability of the technology and equipment being used 'in the environment'. As an example, the use and effect of scene lighting at incidents may cause uncommon patterns of light and shadow leading to unsafe conditions. Narrative reports of injury investigation may indicate this. In time, the provision of technology designed to improve human performance may have unforeseen consequences and should be captured by this category.

People Factors
These preconditions are those that exist amongst the people involved at the time an error occurs some of which are found in the growing debate on situational awareness:

Crew Resource Management (CRM)
First introduced to the aviation industry in the early 1970's CRM captures a broad spectrum of the human aspects of preconditions. Those that crews often impose on themselves that can influence an active error. These are mainly concerned with team communication, coordination and planning. This includes coordination within and between crews and teams at an incident as well as with fire control. It also includes the briefing of crews/teams and debrief/review of task performance and completion. Inadequate planning, lack of assertiveness and inadequate communications can all result in active errors and injury causing accidents.

Personal Readiness
This is about an individual's ability, preparation for, and readiness to discharge his/her responsibilities when on duty. For the FRS this is concerned with an individual's commitment to the individual aspects of the safe person principles. Fatigue and stress which can sometimes be self-imposed, and emotional state can also impact an individual's judgement and decision making.

Individuals' are expected to be both mentally and physically prepared and be competent to fulfil their responsibilities.

Condition of Individuals
This is a difficult category for you to capture in the Phase 2 study because it involves information that can only be obtained by an investigator and you are conducting an analysis of after-the-fact existing information. For the FRS it is also very controversial in that it probes aspects of life style and choice that can influence human error which some may consider to be the 'elephant in the room'. Your view on their relevance and applicability to Human Factors analysis will be sought at the conclusion of the Phase 2 study.

Adverse Mental States
Amongst the 'stressors' that individuals should be prepared for that can impact judgement and decision making are emotional responses influenced by the presence of victims (persons reported). Sometimes this can include peer pressure as well as public expectations and has been described as the 'operational imperative'. Here the impact of 'time pressure' is important where immediate or spontaneous response is triggered by the critical nature of the stimulus. This is also linked to motivation and risky behaviour leading individuals into situations beyond their capabilities. Lack of motivation can have the opposite effect where due to lack of attention individuals fail to seek out information or consider alternatives. Personal emotional state from psychosocial issues often referred to as 'life stressors' and even personality traits such as aggressive behaviour, over confidence, impulsivity, mental fatigue, task fixation, distraction, or even complacency can influence performance and contribute to unsafe acts. Many of these are also known to impact Situational Awareness.

Adverse Physiological States
This category includes medical and physiological influences on individual performance. This will include: the effects of either prescribed or self-administered medication; alcohol; fatigue arising from over-exertion prior to attending for duty; lack of sleep due to illness such as colds or flu or new born sleep patterns as well as disturbance from child illness. Without exposure to fire conditions this can also include inadequate hydration in 'normal' ambient conditions.

Physical/Mental Limitations
Life style issues may also have an impact here where due to body size and lack of fitness an individual simply may not possess the necessary aptitude or physical ability to operate safely. Undisclosed/untreated conditions such as poor eyesight and hearing can affect sensory perception and lead to spatial disorientation. For some, this can include cognitive limitations where memory may be an issue, it may involve misinterpreting or misreading gauges and similar instruments and include missing changes in the environment. Some of these conditions could also be captured as organisational failings in the staff selection process.

HFACS Level 3 – Unsafe Supervision

It is accepted that under the Safe Person Principles individuals are responsible for their own actions and as such are accountable. However, there are instances where they are unwittingly caught up in the latent conditions created by the activities (or inactivity) and influences of their supervisors and managers. These are the conditions that directly affect the actions of individuals and result in human error or an unsafe situation (Shappell & Wiegmann, 2000). There are two aspects to this category. That which is manifest in command, control, supervision and oversight at the scene of an incident, and that which represents the role of supervisors/managers in all aspects of preparation for response. The latter impact performance and include development of policies, methods and procedures. This category has four factors designed to take account of these circumstances.

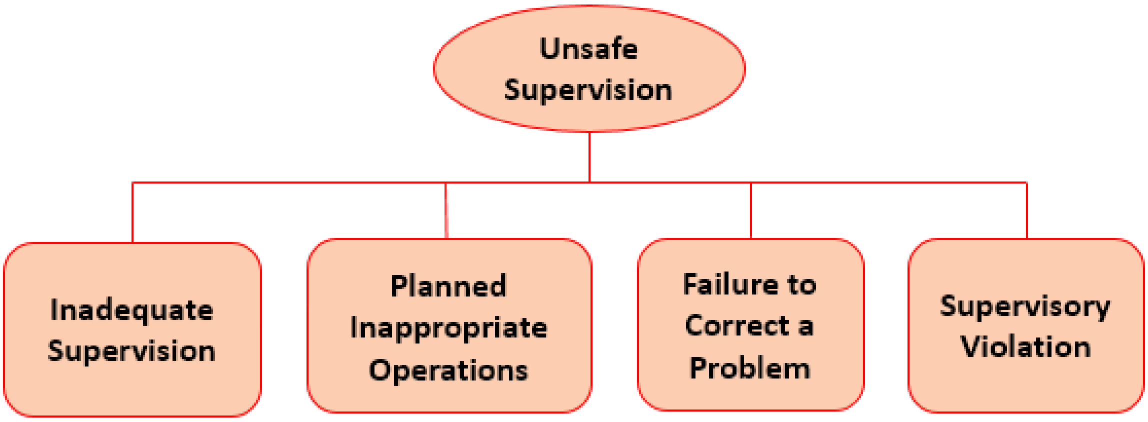

Figure 4 Showing the third level of HFACS. Adapted from Wiegmann & Shappell 2003

Inadequate Supervision
This would apply where oversight or supervision of activities was possible and warranted but inadequate leading to or allowing unsafe situations to develop. Clearly, many aspects of this category apply to both aspects of the role of supervisors/managers. Such as circumstances where information critical to a potential safety issue was provided but not acted upon or where individual risky behaviour is not corrected by appropriate remedial measures. Responsibility for ensuring the competence of individuals is also a factor here. In particular, where individual behaviour is influenced or 'learned' from supervisor behaviour resulting in individuals taking action in violation of SOPs, beyond their level of skill. Inadequate supervision, management, oversight and maintenance of training requirements, sources and materials are also within this category.

Planned Inappropriate Operations
This category is particularly applicable to Incident Command and applies in circumstances where a plan is inadequate or where assessment has not adequately taken account of the hazards involved and allows unnecessary risk. This would include circumstances where a supervisor requires personnel to undertake a task beyond their skill level or the safe operating parameters of their equipment. Aspects of crew choice and rostering are also included in this category. Particularly where through inadequate rest and recovery or crew abilities there is an increased level of risk.

Failure to Correct a Problem
This and the following category are very similar but the most influential factor here is that the supervisor had or has knowledge of the unsafe condition(s). Circumstances where safety is compromised by the unsafe behaviour of individuals; unsafe damaged or unsuitable equipment and/or inadequate training that goes uncorrected are included in this category. However, this can be complicated where no specific policies are infringed.

Supervisory Violation
In a similar way to violations captured in Level 1, this is about the wilful disregard for instructions and policies and includes SOPs and their supporting guidance. It can involve 'permitting' activities not normally accepted within policy where the supervisor fails to ensure existing guidance is implemented. This category also includes circumstances where 'unofficial' local practices are permitted or where individuals are allowed to undertake activities for which they are not 'competent'. This category also captures those circumstances where a supervisor directs an individual(s) to violate existing guidance, which is particularly relevant to the exercise of 'Operational Discretion'.

HFACS Level 4 – Organisational Influences

For the purposes of the Phase 2 study this final level will be largely elusive because there is little after-the-fact information included with the case studies, which suggests they could have been excluded altogether. Even experienced users of HFACS describe difficulty in applying these categories. However, it has been included not only as an important part of the HFACS concept but also to raise your awareness to the value of HFACS in accident investigation. This category relates to the 'corporate' level organisational influences of senior/strategic managers and commanders on the creation of latent conditions. It includes all of those management arrangements that either affect or influence the conditions or actions at the supervisory level and the levels below that result in 'system failure, human error or an unsafe situation' (Shappell & Wiegmann, 2000). You will recognise many of the issues captured under this heading as they are embedded in the growing safety culture and safety climate debate you are familiar with.

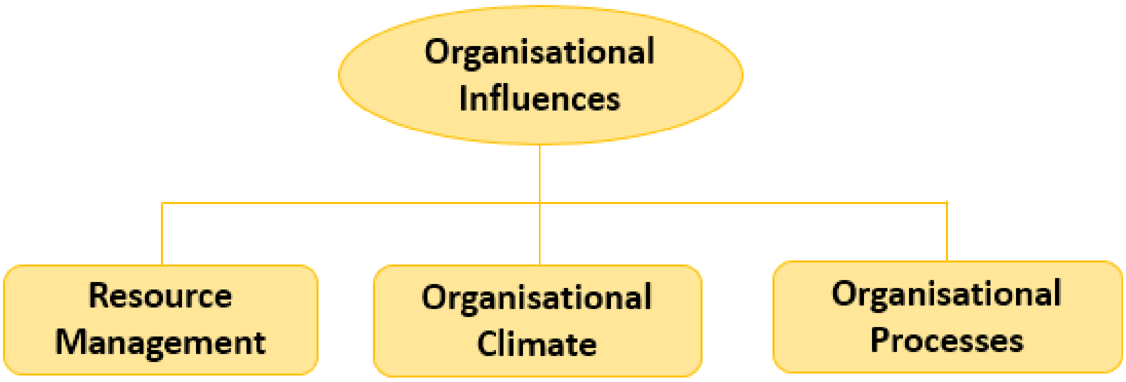

Figure 5 Showing the fourth level of HFACS. Adapted from Wiegmann & Shappell 2003

Resource Management
This category captures three aspects of corporate level resource management: human, equipment and financial. Here the expression human is used with a broad brush that encompasses all those people issues that have an influence on safety. For the FRS these are captured under the 10 organisational responsibilities of the Safe Person Principles (DCLG 2013). All of which are affected by budgets and financial allocations.

In recent years the FRS conflict between providing safe systems of work and cost effective operations has resulted in a significant debate about firefighter safety. HFACS sets out to capture this influence. Consequently, no matter how controversial it has been included here and includes the procurement of, or delay in the procurement of appliances, equipment, personal protective equipment and training including its' suitability.

Organisational Climate
This is where contemporary aspects of safety climate and culture are captured. Core values and factors that influence the way people behave are the main focus of this category. But you should be mindful that the values captured here may not refer to the stated values of the organisation found in an annual report or plan. Often describing the prevailing atmosphere or environment of an organisation a useful definition of organisational climate is: *"…situationally-based consistencies in the organization's treatment of individuals"* (from Jones, 1988, in Shappell and Wiegmann, 2000, :11). Generally, this category includes organisational structure, policies and culture.

Structure

This is about the formal way an organisation organises itself. The organisational tree and people within it, their accountability and the way the discharge of their roles, responsibilities and communication and coordination enable the unsafe conditions that lead to active errors. Factors to consider here would include the interaction with and visibility of managers which may reveal either a lack of or excessive oversight (micromanagement). Another factor is the impact of change management on structures, processes, competence and equipment.

Policies

Seen by some as a good indication of an organisations climate, the influence of policy on accident causing latent conditions can manifest itself in many ways. In particular, when policies are *'ill-defined, adversarial, or conflicting',* they can cause confusion and in the case of SOPs fail to reflect the actual working environment leading to violations that may in turn compromise safety. In some local cases unofficial policy can be used to over-ride them and create independent local values that condone violations. Failure to include adequate arrangements for monitoring, oversight and investigation can also enable unsafe conditions and lead to injury causing accidents.

Culture

Cultural influences are amongst the most difficult to pin down and are one of the reasons why failure at this HFACS level is so difficult to determine but these are the factors that influence attitudes, behaviours and values about safety. One of the influential factors here is the 'just' nature of the organisation when dealing with errors and violations. Is the organisational response one of blame or one of understanding of the latent condition's that allow error to occur? The existence of sub-cultures at the watch and station level that do not follow organisational policy or adhere to selective SOPs is an aspect of the cultural influence. Expressions such as *"…the way things really work around here,"* are indicative of the existence of unspoken or unofficial rules.

Organisational Processes

The primary influence under this heading lies in the way the rules of strategic decision makers shape the way work gets done. For a Fire and Rescue Service the most obvious example is the Standard Operating Procedures designed for safe incident operations. This not only includes how they are developed, revised and published; but also applied in operations. The same would apply to the guidance provided for routine work. Also captured under this heading are the processes used for maintaining oversight of safety 'rules' and the way working practices are monitored by 'management'. This category would include any aspect of a Fire and Rescue Service management process that can affect safety such as work routines and shift patterns. Arrangements for monitoring the suitability and use of resources, behaviour and safety climate would also be included in this category.

<u>Conducting the Case Study Analyses</u>

Hopefully, now you have an idea of the main levels and sub categories of HFACS you will be using in this exercise, the guide will now take you through the process of conducting an analysis and selecting the various categories you believe best represent the issues revealed in the case studies.

A case study accompanies this guide. It is the first of two you will be using for this phase of the research. You will be familiar with the incident and the report on which it is based. At all times whilst completing this HFACS analysis, no matter what your knowledge of events identified in the case study or your knowledge of the report from which the case study is compiled, **you must only use the information provided in the edited case study to complete the exercise.**

You also have a workbook which is in the form of an excel spreadsheet but for those that find it useful I've also included a word document that you can print and use for writing your responses. If you haven't already taken a look at them perhaps now may be a good time. You will first notice that it has a simple cover page with the step-by-step version of this guide. This also brings your attention to the tabs at the bottom of the workbook each of which you will notice is colour coordinated to and matches the four main Levels of HFACS described above. When you open each tab you will also notice that they include a sub category or more specific descriptor of the activity at each level.

Where these sub categories are concerned, this is the first time HFACS is being applied to the UK FRS domain. But you may find some of the information provided above helpful in understanding their meaning. The sub categories provided have originally been used in other domains, mainly those identified in Table 1 on page 3 above. Hopefully, editing them down to those included in the worksheet has excluded many that don't apply. However, if there is a UK FRS specific sub category not included that you have identified in the case study, or one you would like to see included please add it in the row identified with a question mark.

The first case study has six sections of information you should use in the analysis; these relate to: a) knowledge of the building; b) knowledge of Incidents previously attended; c) a time plot of the incident; d) a time plot of the search and rescue operation; e) description of activities of the casualties; and f) some additional information relevant to the case study.

As accident investigators you will find some statements in the case study suggest a possible error but with little supporting information on which to make a judgement of causation. At times you will find this frustrating. The case study is, after all, only a summary of quite a detailed report and you may feel at times an unreal summary at that. It should help to keep in mind that you are not conducting an accident investigation but seeking evidence of the unsafe acts and some of the preconditions that may have influenced or permitted them. Adding these to evidence of unsafe supervision, and should you identify any, the organisational influences that may have contributed to the unsafe acts, completes a human factors analysis but not an accident investigation.

There a number of approaches you can take to working through this exercise and what follows on the next page is simply one approach. If after trying it, you adopted a different approach which you found easier then please provide a description with your feedback. Please also note how long it takes you to complete your analysis. The trials reported a variation of 2-3 hours to read through all the documents and a further 2 hours to complete the case study analysis.

Step-by-step analysis:

1. Ensure you read through this document and are familiar with the main and sub category descriptors of each of the HFACS levels and supporting information.

2. Ensure you have read through the case study.

3. Using any style that suits you annotate the margins of the case study with the Level of HFACS that you believe to be relevant in the text as you read it, they each have an alphabetical identifier **A - D**.

4. Having identified the main **HFACS Level** now identify the factor of the **main category** of that level that you think it reveals. You could do this by adding to the original annotation with the main category number found in the workbook in the margin. As an example only and not designed to influence your choice, if you have detected information relevant to the **Main Category B** in the previous step, and it involves the factor of 'personal readiness' your margin annotation would now be: **B.4**

5. After applying the main category annotation, now review all the annotations with the same number (all the B.4's) and consider which of the **sub category** descriptors best captures the factor you believe to be revealed in the text of the case study.

6. Either at the conclusion of the margin annotation exercise, or if you prefer, as you make them, transfer your selection to the workbook row by entering a ✓ in column 4. You could also use the word document 'notation' pages for this.

7. Where you think you can add another Sub Category descriptor please enter it into the cell of the row with a **'?'** but please ensure it's not a different descriptor for a sub category that already exists. If you do have an alternative or better choice, please make this clear in your feedback.

8. If you feel it's important to explain the rationale behind your selections, please use the text box at column 5 on the spreadsheet to record your thoughts.

9. It may well be the case that you identify several examples of the same sub category factor (B.4.4). You will see the spreadsheet has 5 columns where you can indicate a factor repeating itself. Should it be the case that you have more than 5 repeats completely black out the final cell for that row.

10. When you are not sure about a piece of evidence such as the issue of mechanical ventilation for example - is it a sound judgement or maybe a decision error? The choice must be yours but please explain the rationale you used to make it.

You will by now believe that many of the sub category descriptors are difficult to apply and interpret. This is because we are trying to shape more appropriate phrases with your help. You will also have realised that the case study does not contain enough information to capture much of the 'Organisational Influences'. Not only is this normal but without you having conducted a detailed causal factors accident investigation, impossible to achieve.

Now we should consider your post analysis feedback. If you found an easier way of achieving the analysis process, please describe what you did in your own words. You can do this in an e-mail or provide a document as an attachment with your reply.

The most important document is of course the excel workbook and the entries you have made that identify the factors you believe to be present in the case study. Where you have provided additional sub category descriptors an explanation would be helpful. Above all else, if there is anything you think would improve the HFACS tools you have encountered in this exercise please let me know.

All that remains is for me to thank you for your continuing support and participation in the Firefighter Injury research project.

Bill Gough

NB References on request

Appendix 2

Background and briefing documents for Study 2, Case Study 1

Firefighter Injury Research Project

Phase 2 Case Study 1 – Atherstone-on-Stour

Bill Gough Coventry

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Contents

Figures

Introduction

At 17:40 on 2nd November 2007 Warwickshire Fire & Rescue Service mobilised to a building fire at Hanger 1, Wealmoor Atherstone Ltd, a vegetable packing and processing facility in Atherstone-on- Stour a small rural village 4 miles south of Stratford-upon-Avon, a fire in which four firefighters lost their lives. Firefighting operations involved several attempts to locate the fire but, despite having onscene advice from Wealmoor's engineering manager, crews were unable to locate and tackle the fireuntil it breached the building three to four hours into the incident.

This was the largest and most complex incident Warwickshire Fire & Rescue Service had attended inrecent history and required regional and national support to bring operations to a conclusion. It wasfour days into the incident before all four firefighters had been recovered from the building and it took another day to finally extinguish the fire completely.

This case study first provides a general description of the building and some of its recent history, before identifying brief details of incidents previously attended by crews from Stratford-upon-Avon.The case study then explores the initial search and fire attack operations of the incident on 2nd November and WFRSs response from the approximate time of discovery of the fire at 1720 hrs to the declaration of the BA emergency at 1915 hrs. The section that follows then provides an accountof the initial search and rescue attempts until 2122 hrs, when due to the risk of collapse *"all BA crews are withdrawn".*

Fire investigation that followed summarised that:

- *The fire was started deliberately by the application of a naked flame ignition source to combustible material that was located at the end of a large store room on the first floor inthe centre of the Building;*
- *the design of the first floor store created a compartment which was well insulated withlimited ventilation but with sufficient air to allow the fire to develop;*
- *a number of fire protection measures within the building were incomplete which alsoassisted in the development of the fire; and*
- *due to the construction and layout of the building, firefighters were unable to reach the firein the early stages to extinguish it. This led to the development of a severe fire which ultimately destroyed over fifty percent of the building and led to the death of four firefighters."*

The Building

It is important for participants in the Phase 2 case study to note that full details of the building's construction were only discovered after the incident and crews attending the fire on 2nd November2007 did not have this information. The exact layout of the building on the night cannot be confirmed, as no built plans were finished and parts of the building were destroyed during the fire.

However, the case study provides a brief description of the building and its pre-fire history. The original warehouse was based upon a World War II hanger sited on an old airfield. The hanger hadbeen extensively developed and extended which doubled the size of the building to approximately150 x 69 x 10m (Figure 1). The building consisted of three different stages of development, with varying construction types.

Figure 1 Aerial view of warehouse showing the original (aged) roof and the roofs of three further stages of extension and the large building footprint.

In 2002 a planning application was put forward to use the site again as a private airfield. Warwickshire Fire and Rescue Service (WFRS) identified the need for further water supplies againstthe proposed development and wrote to the applicants, but the proposal never went ahead. A building regulations consultation took place in 2003 over the conversion of the hangar to a chill store. In March 2004 a planning application and building regulations consultation took place over the fitting out of an existing unit (believed to be a 1999/2000 extension), with cold storage and 1st floor offices. The application was eventually rejected when further information requested was not supplied. The application was not progressed but the 'incorrect' plans were amongst the ones provided to WFRS on 2nd November 2007.

In June 2007, towards the end of the construction process, the owners at the time, Bomfords Ltd went into insolvency and administrators became responsible for the business. In August 2007 Wealmoor Atherstone Ltd purchased the building and the associated business. They continued to use all areas of the new extension where the fire occurred, with restrictions on access to and use ofthe storage area, whilst assessing what further work was required to complete the building.

The building had a fire alarm and detection system throughout, with extinguishers and signage also in place. A fire risk assessment was completed by a contractor for Bomfords Ltd covering the groundand first floor, but not the storage area, by 21st March 2007. The storage area was considered to be under construction so was not included in the risk assessment.

Building control last visited the site in March 2007, when the first floor office area was nearing completion, the area was unoccupied and doors still needed fitting to the internal escape staircases.Shortly after this Bomfords Ltd went into administration and construction work ceased. Building control has stated they were unaware that the first floor was occupied at the time of the fire in November 2007. Building regulations approval for a building where fire safety legislation applies should follow a defined process. This process includes a statutory duty to consult with the local fire authority once building control are minded to approve plans, so that they can advise on firesafety legislation requirements that will be enforceable when the building is occupied. These processes could be used to identify buildings that may require premises risk information to be gathered as part of section 7.2(d) of the Fire and Rescue Services Act.

The first floor of the new extension had offices, staff rest areas, a lift lobby and a storage area. In a room on each side of the building, off the lift lobby, is where the Air Handling Units (AHUs) mentioned in the following section are to be found, which also held the heating and air-conditioningsystems for the office area. The first floor storage area was served by a single entry point (travel distances exceeding requirements of the building regulations).

Previous Incidents

The warehouse had two known fire incidents prior to 2nd November 2007. On 3rd September 2006, two fire appliances from Stratford-upon-Avon attended a report of a strong smell of smoke. This involved a broken machine belt in plant outside of the back of the building. On 20th April 2007, twofire appliances from the same station attended a fire involving a compressor.

The whole-time appliance was crewed by the same watch that attended on 2nd November 2007. The fire was located in an air handling unit (AHU) room off the lift lobby on the road side of the building and was extinguished by Breathing Apparatus (BA) crews using extended hose reels. Smoke had spread to other rooms as a number of self-closers on doors were disconnected. On return to station the incident commander asked a WFRS fire safety officer to attend the premises, which they did thatmorning.

The fire safety officer was escorted on site by the maintenance manager for Bomfords Ltd (the same person was later the engineering manager at Wealmoor on the 2nd November) and the project manager for the new extension. He was taken to the area were the fire had occurred, found no doors propped open and the self-closers properly connected. It was discussed that the fire doors hadbeen held open to ventilate and cure newly laid flooring in the area.

The fire safety officer also found a 4m x 3m gap leading to an area he referred to as the chill store. The gap exposed the mineral wool sandwich panels. It was discussed that the gap had been made toallow the installation of fridge units, and that a fire door was to be installed in the gap. Advice was also given about the positioning of smoke detectors, the importance of maintaining compartmentation and keeping doors closed, maintenance of fire precautions throughout the construction phase, and the need to carry out a fire safety risk assessment.

Neither the September 2006 incident, the April 2007 incident nor the subsequent fire safety officer visit identified the need for an operational premises risk assessment to be carried out under section7.2(d) of the Fire and Rescue Service Act.

The Incident

During the afternoon of the 2nd November 2007, a stock control check was carried out to identify items for recycling and disposal. At around 1700hrs, the packaging lines are completed except one which is overrunning. Workers on this line continue to work to finishthe packaging of the vegetables.

The nearest fire station is at Stratford-upon-Avon, which has one whole-time and one retained dutysystem appliance. Apart from Stratford-upon-Avon the majority of fire stations in the south of the County are one appliance retained stations, with the next nearest whole-time station being at Leamington Spa, approximately 30 minutes away.

17.20

The automatic fire detection system sounds the alarm.

17.24

The engineering manager, having already left the site, is contacted and informed that the fire alarmhas activated. He returns to the building to investigate. After attempting to silence the alarm, he goes to the first floor storage area where the alarm panel indicated the detector had gone off.
He sees a pallet, stacked with cardboard boxes, on fire within a bay at the far end of the store room.
He attempts to put out the fire using a foam fire extinguisher. This extinguisher runs out so he locates a carbon dioxide extinguisher and attempts to put out small pieces of paper like material that had drifted away from the pallet. He believes that he has successfullysmothered the fire and leaves the building to get help from other staff.

He returns with five other people. They find that the pallet has re-ignited with the flamesnow reaching the ceiling. They realise that it is safer to leave the building and call 999.

17.35

An employee calls the fire and rescue service using his mobile telephone. The call is routedto Gloucestershire Fire and Rescue Service (GFRS).

17.37

GFRS pass the details of the call to WFRS. The use of the building (‘*packhouse*’) is not passed overand WFRS do not record the postcode.

17.40

WFRS send two fire appliances from Stratford-upon-Avon.

17.52

The first fire appliance (whole-time) arrives. At this point there are no signs of fire fromoutside the building.

17.54

The second fire appliance (retained) arrives.

The officer in charge (IC1) is met by the engineering manager. They recognise each otherfrom the incident in April 2007. They discuss the situation; IC1 asks what is on fire, its location and surrounding hazards. They enter the building, via the visitor’s entrance (Figure 2) andgo to the first floor reception area.

Figure 2 Showing the initial entry point and adjacent roadway on which the first crew arrived.

From here they enter the corridor and IC1 sees smoke seeping through gaps in the double doorsleading to the lift lobby at the far end of the corridor.

The description from the engineering manager is taken to mean the fire (indicated by the flame iconin Figure 3), is just beyond the double doors at the end of the corridor. No direct question is asked about evacuation, with the general understanding being that the building is evacuated.

A Breathing Apparatus Entry Control Point (BAECP) is established outside the visitors' entrance.Stage 1 BA procedures are put in place.

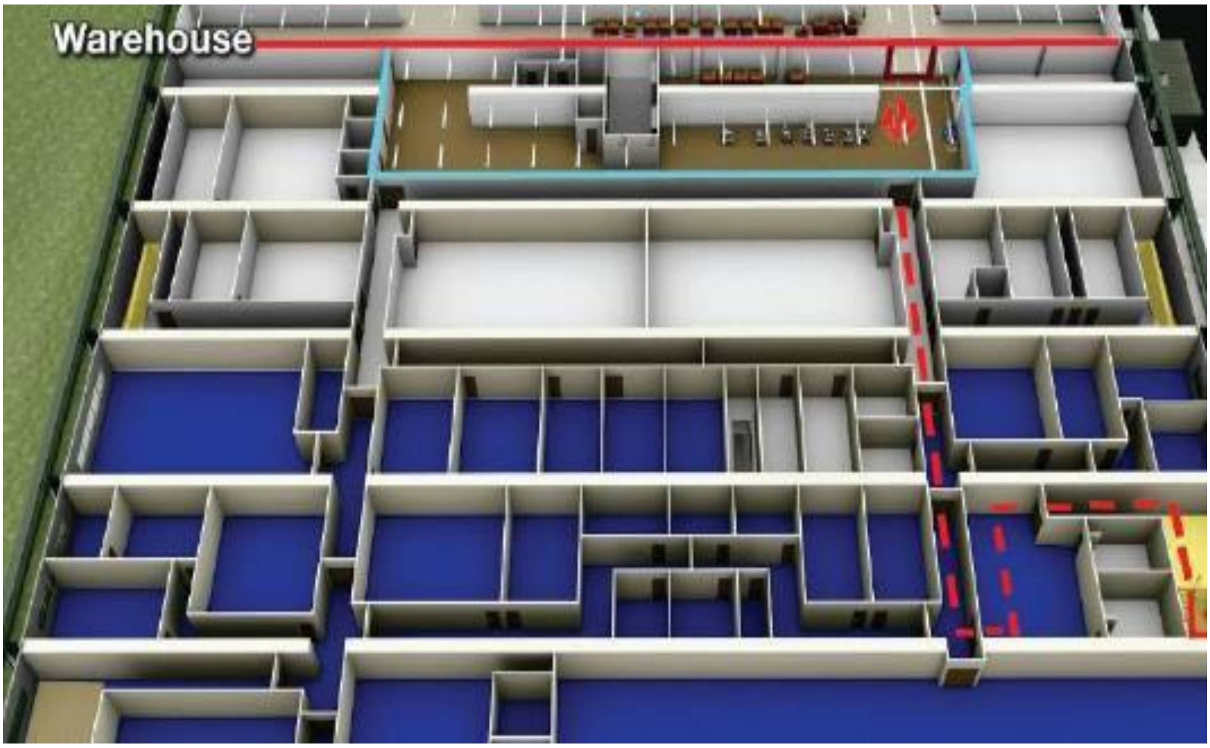


Figure 3 Showing the route taken by the engineering manager and IC1 on their entry to the long corridor where smoke is seen seeping through the double doors at the end of the corridor and the assumed location of the fire beyond.

IC1 exits the building to brief the crews. There is no visible smoke in the corridor. The first 2-person BA team (BA1) enters the building with a hose reel with a brief to locate and extinguish the fire. Theyget to the first floor and move along the corridor to the double doors giving access to the lift lobby (outlined in blue). There is still no smoke build up in the corridor and the lights are still on. They reach the double doors and see 'wispy' smoke coming from around the edges of the door.

18.04

Informative message from IC1:

"Building of 2 floors, 100m x 100m, use undetermined,
fire on 1st floor, HR jets, 2BA, offensive".

BA1 enter the area they believe to be the fire compartment. They encounter thick black smoke down to floor level, with limited visibility, but neither firefighter expresses concern over the heat.

Unable to locate the fire, and with the hose reel pulling tight, BA1 withdraw back into the corridorand radio for more hose reel.

This is extended outside and they go back into the lift lobby, wedging the inward opening doors open with a pallet and two boxes. Still unable to locate the fire they request a thermal image camera(TIC) via radio. IC1, who has been monitoring their progress from a safe position further up the corridor, checks the TIC and takes it down the corridor to them.

The TIC screen, when used in the compartment, shows a blank screen with no contrast or image.

IC1 is informed by the engineering manager of the water supplies available on site, a borehole at thefront and a 16000 litre tanker on the wooded side of the building. Having still not located the fire, IC1 tasks two firefighters to check the opposite side of the building for signs of fire and assess water supplies.

BA1 make the decision to withdraw as they are low on air. With the double doors propped open,smoke is starting to build up in the corridor.

Approximately 1815

The second 2-person BA team (BA2) enter the building to relieve BA1. The teams meet in the corridor and exchange information. The smoke at this point is 2m off the ground and white in colour.BA2 take the TIC and check it is working. As they move into the lift lobby the screen display shows a blank screen with no contrast or image.

BA2 advance on their knees, gas cooling at regular intervals, on a right hand search, they come to apoint which is noticeably hotter and they cannot hear or feel water coming down. BA2 put a figure of eight pulse spray out in front; as they are concerned the short and long gas cooling sprays aren'teffective. They are hit by a wave of heat which they believe to be steam from something very hot.

BA2 withdraw from the building in an agitated state. By this time smoke is down to ankle level inwhat they perceive to be the fire compartment (but is actually the lift lobby).

Outside the engineering manager assists firefighters to draw a plan of the route to the fire on the back of the BA board (Figure 4). The fire is further into the compartment than they were originallyinformed: now understood to be 18 – 22 metres through the double doors and off to the left.

Figure 4 Showing the sketch drawn on the back of the BA Board. The double doors at the end of the corridor can be seen at the bottom right of the sketch, indicating an approximate distance of travel to the fire indicated by the arrow.

18.28

Assistance message from IC1:

> "*Command level 1 make pumps 3 for BA as we are having difficulty locating seat of fire due to size of premises*".

18.30

A BA tender is mobilised in addition to appliances requested.

18.34

Night shift crew (in a 4x4 with IC2) arrives from Stratford-upon-Avon fire station to relieve whole- time day shift. One of them describes seeing smoke slowly drifting upwards from somewhere in thecentre of the building from under the eaves of the building, with the entry control point clear of smoke at this point.

They set up a covering jet and a BA servicing area. IC1 requests a third BA crew (BA3) to continue the search for the fire. The first crew (BA1) now rested and with improved information, agree to goback in. They re-enter the building following the same route and IC1 follows them to a safe point inthe corridor, having to bend down to see under the smoke. Their brief is to progress into the lift lobby area (believed to be the fire compartment), leave the reference wall and to progress beyond two partitions located ahead and slightly left, to find the fire location and then extinguish it.

BA3, on their hands and knees, experience nil visibility and an increase in temperature from their first BA wear. They reach the first partition approximately 5m inside the lift lobby, as expected.They start to move around the end of the partition but team leader gets caught by some cables hanging down from the ceiling (plastic trunking has melted releasing the cables). The No.2 in the team releases him.

BA3 note the temperature increases significantly as they move around the end of the partition. Theylook to go ahead and slightly off to the left for the second partition and encounter an unexpected triangular structure impeding their progress. They make radio contact to seek clarification but this structure cannot be verified.

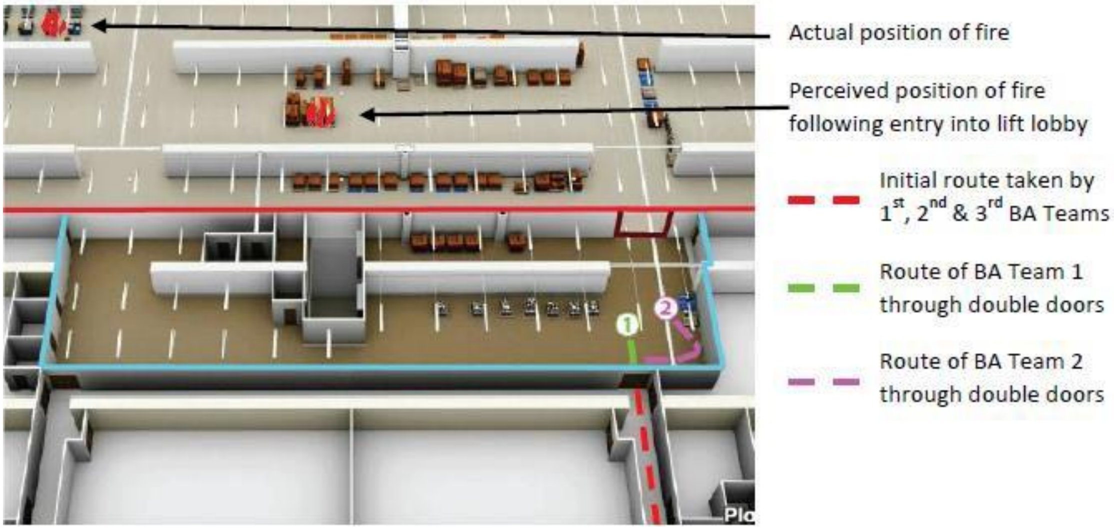


Figure 5 Showing how the actual location of the fire differed from the second 'perceived' location indicated by the arrow drawn on the back of the BA Board.

18.37

A third fire appliance (retained) from Alcester arrives. Crew notice white/grey smoke coming fromthe eaves of the building.

18.38

Assistance message from IC1:

"*move to command level 2*"

(this is a make pumps 5 plus additional command support pump).

The reconnaissance for water supplies and signs of fire is completed. The firefighters inform IC1 theyhave not seen any external signs of fire spread, some water flowing from pipes from within the south side of the building, and smoke from ventilation ducts adjacent to the appliances on the road side. They also report unsuitable firefighting water supplies on site (connections not compatible).

Assistance message from IC1:

"*request attendance of water bowser*".

Smoke is getting noticeably thicker on the outside of the building around the BAECP. IC1 and therelief (IC2) go to the first floor to review the situation. Smoke has now entered the first floor reception area.

BA3, still unable to identify a triangular structure are concerned that they have gone off route and decide to withdraw from the building. Conditions are described "*extremely hot*".

Command support (two firefighters in an appliance) is moved from the road side of the building, near to the visitors' entrance to the hard standing at the front of the building. The smoke is hanging in the air and falling down to the ground as it is not hot enough to dissipate upwards.

IC1 considers ventilation from the roof, after discussing building construction with the engineering manager and concludes it is not feasible without specialised equipment. BA3 exit the building and initiate further discussions for venting of the fire. They then draw a new plan using the Command Support pack in consultation with the engineering manager.

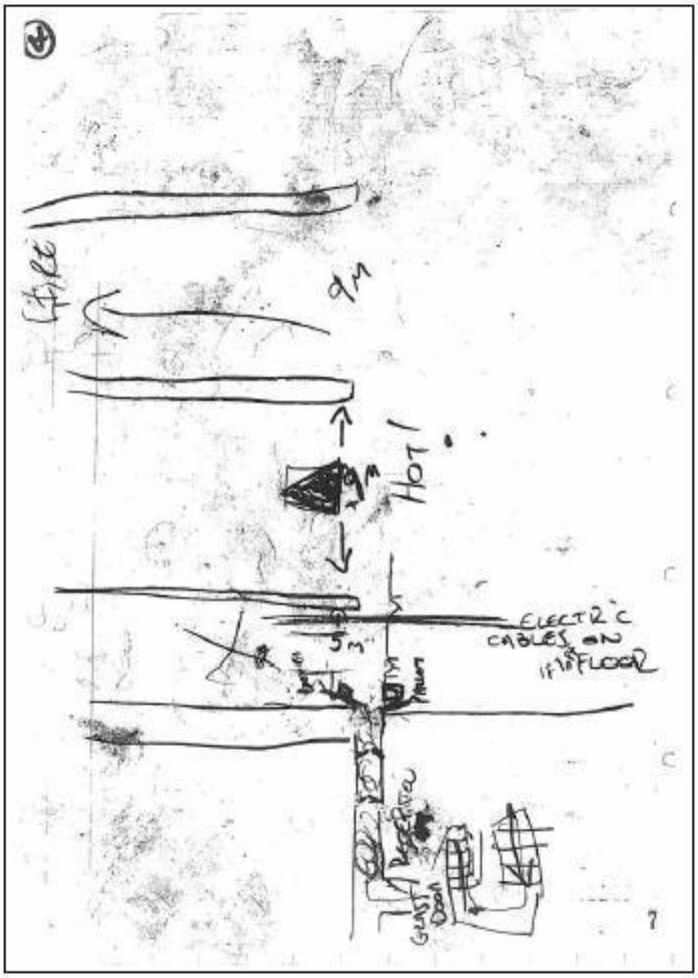


Figure 6 The new plan drawing which indicates the suspected location of the fire, distances to the fallen cables, partitions, unknown triangular object, and indicating hot conditions at the triangular structure.

18.48

IC2 takes over command of the incident from IC1 (approx. 2 minutes before next assistance).

18.49

Fourth appliance (retained) from Wellesbourne arrives. There is no heavy smoke and no flame visible from outside. The crew observes no blackened windows and the smoke is misty *"like steam"*.

18.50

Assistance message from IC2:

"move to Command Level 3"

(This is a make pumps 8, plus officer support)

18.52

Fire cover officer arrives (station manager). He notices light grey smoke coming from the eaves ofthe building.

18.53

A four-person BA team (Red 1) enter the building with a brief from IC2, using the new plan drawing(Figure 6), to carry out a right hand search of the fire compartment, locate and extinguish the fire and report back on conditions inside. They are tasked, if possible, to find an alternative entry point and look for ventilation options. Prior to Red 1 entering they are given information about the suspected location of the fire, the location and distances to the fallen cables, partitions, the unknown triangular object, and the fact that conditions are very hot in the area around the triangular structure.

They take with them an extended hose reel. Light smoke is still coming from the eaves of the building and the first floor lights are still on. The rooms seen through the first floor windows areclear of smoke.

A team, without BA, manage the hose reel for Red 1 in the first floor reception area (top of the stairs). The first floor landing is clear although there is smoke in the reception area and the corridor.

Their time of whistle is recorded as 1928 hours on the BA entry control board.

18.55

Fifth and sixth appliances arrive. The crews observe smoke coming from the eaves of the buildingbut no flames and the lights are still on in the first floor windows. Fire cover officer (IC3) takes command of the incident from IC2 and as part of the handover a review of the situation is undertaken.

Smoke is at head height in the first floor reception area. IC2 observes no difference from before; it is*"normal black smoke*". IC3 sees smoke but no fire or sound of fire is heard.

Ventilation is discussed once again. There is a mechanical ventilation system in the building but a reluctance to use it because of uncertainty as to where it will spread the fire.

Smoke is dropping around the BAECP. Two firefighters are sent around the outside of building looking for another point of entry. On the south side of the building, at the eaves, they notice a section of the steelwork is glowing red (Figure 7). IC2 is informed of the situation on their return tothe BAECP.

A team is tasked to secure water supplies on the wooded side of the building and to set up firefighting jets.

Breathing Apparatus Entry Control Officer (BAECO) is relieved by the night watch and Stage 2 procedures are implemented.

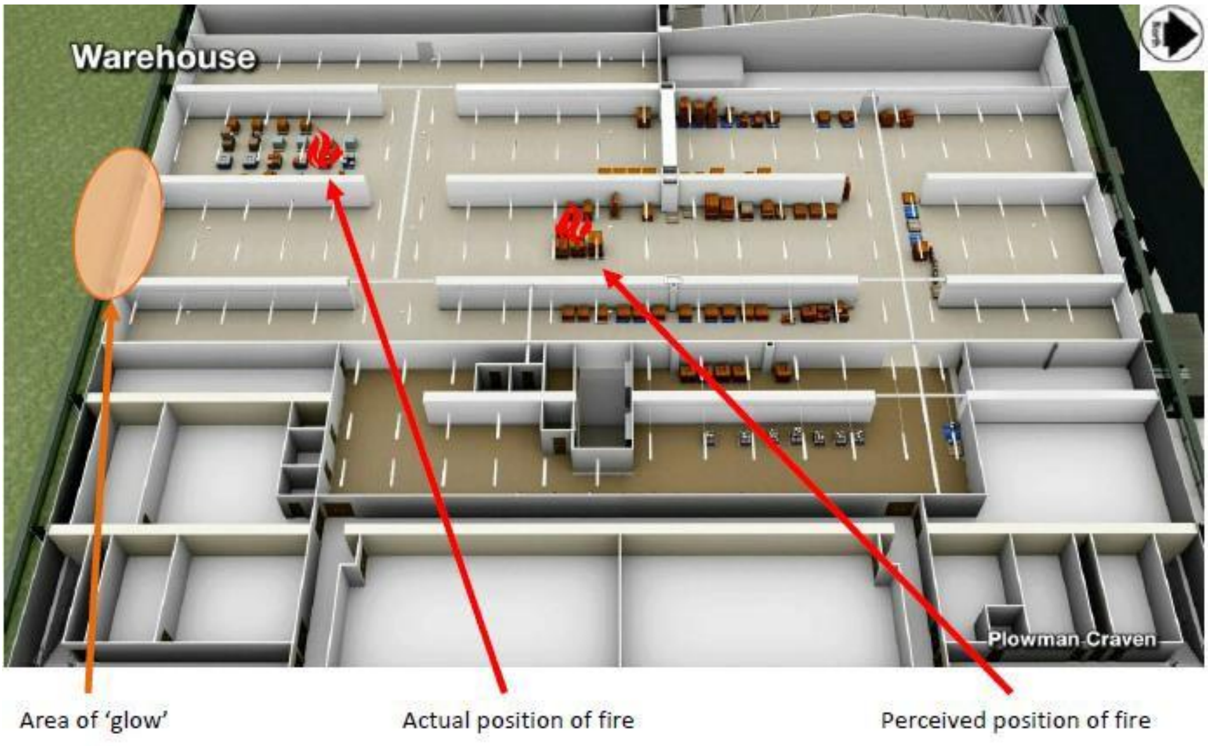


Figure 7 Showing the original 'perceived' location of the fire, the actual location and the area where a glow is seen externally

19.07

Another four-person BA team (Red 2) enter the building with a brief from IC2 (now acting as sector commander) to carry out a left hand search of the fire compartment to locate the fire, extinguish itand look for ventilation options. They take with them an extended hose reel.

A two-person BA team relieve the team managing hose in the first floor reception area. They find thestairwell and reception clear of smoke with hazy smoke in the corridor leading to the lift lobby.

A crew is sent to the south side of the building to reassess the water supply from the tanker. They observe the wall glowing red past the second exit door on that side. This information is passed to IC3approximately 3 minutes later (Figure 8).

IC1 enters the ground floor with the engineering manager. The ground floor was "*absolutely clear*" ofsmoke. They open a fire exit on the road side (which later becomes the second Entry Control Point).

Red 2 go through the double doors and enter the lift lobby. The smoke is down to floor level with poor visibility and the heat is described by the `team as "*intense*", "*a punch on the nose*" and "*like an oven*".

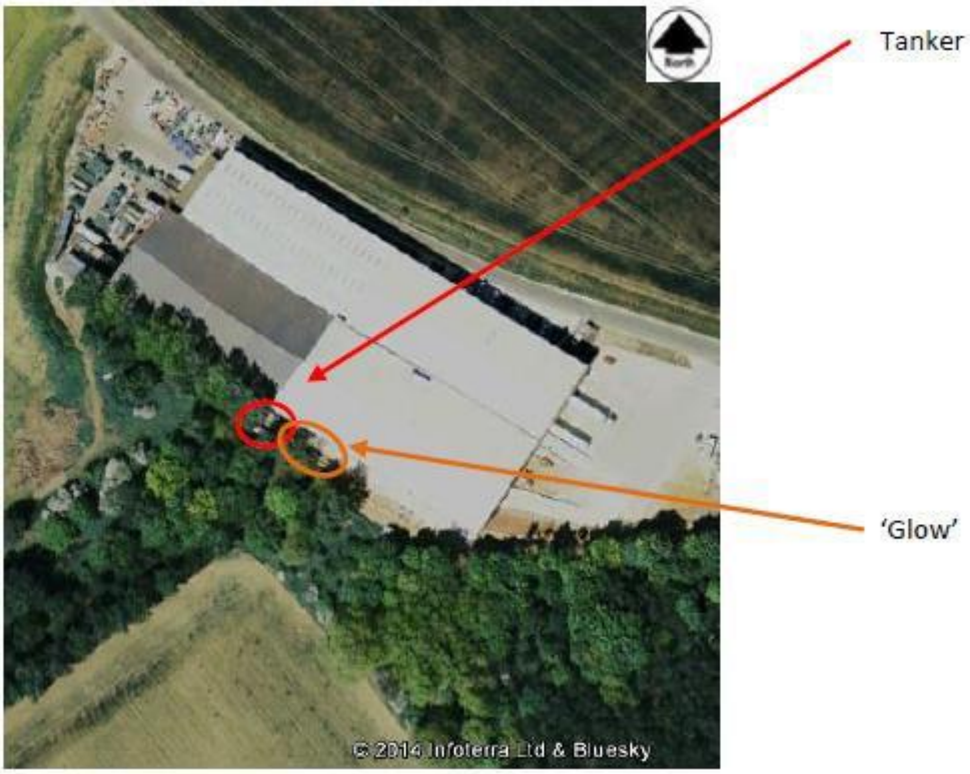


Figure 8 Showing the south side of the building where a crew sent to assess the water supply from the tanker observe the wall glowing red past the second exit door on that side.

The intensity of the heat is growing rapidly. They notice the hose reel from Red 1 going to the rightand the team leader is aware of Red 1 in front of him and can hear them speaking.

Gas cooling is having little or no effect.

Stratford-upon-Avon's day watch with IC1 leave the incident ground.19.11

Seventh appliance arrives from Leamington. The crew see smoke coming from the roof but no visibleflames.

BAECP officer loses radio contact with Red 1 and immediately informs IC2.

Two members of Red 2 hear a loud crash and bang from within the fire compartment. BAECO hearsan unreadable message over the radio. IC2 takes the BAECP officer's radio and calls up Red 1. He hears the words 'emergency, emergency'.

Red 2 are concerned about worsening conditions and decide to withdraw. They retreat a short distance and from just inside the double doors the Red 2 team leader hears Red 1 roughly 9m awayand to the right. He hears large objects falling down.

19.15

Red 2 hears 'BA Emergency' over the radio. Red 2 takes a gauge check and tries to contact the BAECO on the radio. They hear Red 1 starting to move from right to left, putting them directly infront of the double doors.

Red 2 have difficulty contacting the BAECO. They withdraw into the corridor slightly and, after adelay, they establish contact with the BAECP and are instructed to find Red 1.

Red 2 team leader (No 1) and his number two (No 2) re-enter the lift lobby to search for Red1 whilst numbers three and four (Nos. 3 & 4) manage hose at the double doors.

Red 2 Nos. 1 & 2 can hear Red 1 in the lift lobby; they are shouting, sounding more agitated and moving further to the left. They hear rhythmic banging noises like "*a BA cylinder being hit on the floor*" or "*pallets falling over*".

Red 2 Nos. 1 & 2 follow their left hand wall, in the direction of the noises from Red 1. The temperature is rising; smoke levels are increasing in the corridor. They hear noises of somethingwooden being kicked. They shout to alert Red 1 of their presence.

Red 2 No. 1 senses that someone is close by and moves out from the wall, he is nearly 2m off thewall with his back to it. They continue to gas cool.

A firefighter from Red 1 appears out of the smoke in front of them. He does not speak and is staggering. Red 2 No.1 (Figure 9) grabs hold of him and pushes him towards the wall and the firefighter follows the wall, bursting past Red 2 No. 2 towards the double doors. Visibility is verypoor.
Red 2 Nos. 1 & 2 remain in the lift lobby area, expecting the other three members of Red 1 to appear.
The firefighter from Red 1 locates the double doors and exits the lift lobby to the
corridor. He bursts through the doors at speed passing Red 2 Nos. 3 & 4, who are unable to seizehold of him, and disappears into the smoke with his low pressure warning whistle on his BA set going off. Visibility in the corridor has deteriorated and Red 2 Nos. 3 & 4 believe him to "*have progressed back out".*

Red 2 Nos. 1 & 2, still on the left hand wall within the lift lobby, continue to search for the remainingthree members of Red 1 and reach the full extent of the hose reel. The shouting and banging that they could previously hear stops and they hear automatic distress signal units (ADSU) for the first time. They take a few steps beyond the end of the fully extended hose reel. The heat becomes unbearable, visibility is nil and they are becoming exhausted. Therefore, they decide to withdraw from the lift lobby but leave their hose reel in place thinking it may act as a guide to safety for others.

Initial Search and Rescue

While Red 2 were attempting to find the missing members of the Red 1 team, believing that one of them had been rescued; the focus of the operation outside changed from fighting the fire to searchand rescue. Four firefighters were still missing and the role of WFRS was to find them as quickly as possible.

19.15
"BA Emergency" message sent to Service Control.

A three-person BA team (Emergency Team 1 or ET 1), who had been standing by under Stage 2 procedures, enters the building with a brief to locate and rescue the missing team. They take with them a line of 45mm delivery hose. They make their way through the first floor reception which wasrelatively smoke free, but the smoke gets heavier as they make their way down the corridor. On their way down the corridor they meet with Red 2 and exchange information.

ET 1 reach the end of the corridor, their 45 mm hose will only take them as far as the double doorsto the lift lobby. Following the advice from Red 2, they follow the hose reel to the left into the lift lobby where visibility is very poor and the temperature extremely hot (Figure 9).

Assistance message from IC 3:

"request attendance of ambulance service".

In response to the BA Emergency message all crews, including those previously allocated to other tasks on the incident ground, gather at the entry point with BA sets. This includes the sixth appliancein attendance which should have been dedicated to enhance the Command Support function.

A four-person BA team (ET 2) enters the building with a brief to locate and rescue the missing team.They take with them a line of 45mm delivery hose and a TIC. They follow the same route as ET 1 andreach the extent of their 45mm hose at the double doors to the lift lobby. They pause there and experience a temperature so great it forces them onto their knees.

IC 3 updates his previous message to control, establishing that there are potentially four casualties.

19.26
Second Fire Cover Officer arrives (station manager). There are no visible flames from the building asthe fire has not broken out, but he sees a plume of white/grey smoke.

ET 2 hears the sound of an ADSU to their left. The crew separates; two stay on the branch, and two head towards the sound of the ADSU. They briefly go in through the double doors to the lift lobby, before realising the ADSU is actually coming from a different area. They backtrack and go down a side corridor to their left. A firefighter from Red 1 is located two to three metres down this side corridor (Figure 9). He is still wearing his BA set and his helmet is dislodged but still on. There are noaudible indications of breathing.

An ET 2 crew member attempts to search for further members of Red 1 using a TIC, but the screendisplays no contrast or image in the now heavily smoke logged corridor. After quickly searching around and finding no other casualties, ET 2 begin to make their way out of the building with the casualty.

ET 1 also hears ADSUs in the lift lobby. They make a noise banging on the wall and get to theend of the hose reel left by Red 2 on the left hand wall, but the increasing heat forces their withdrawal from the lift lobby.

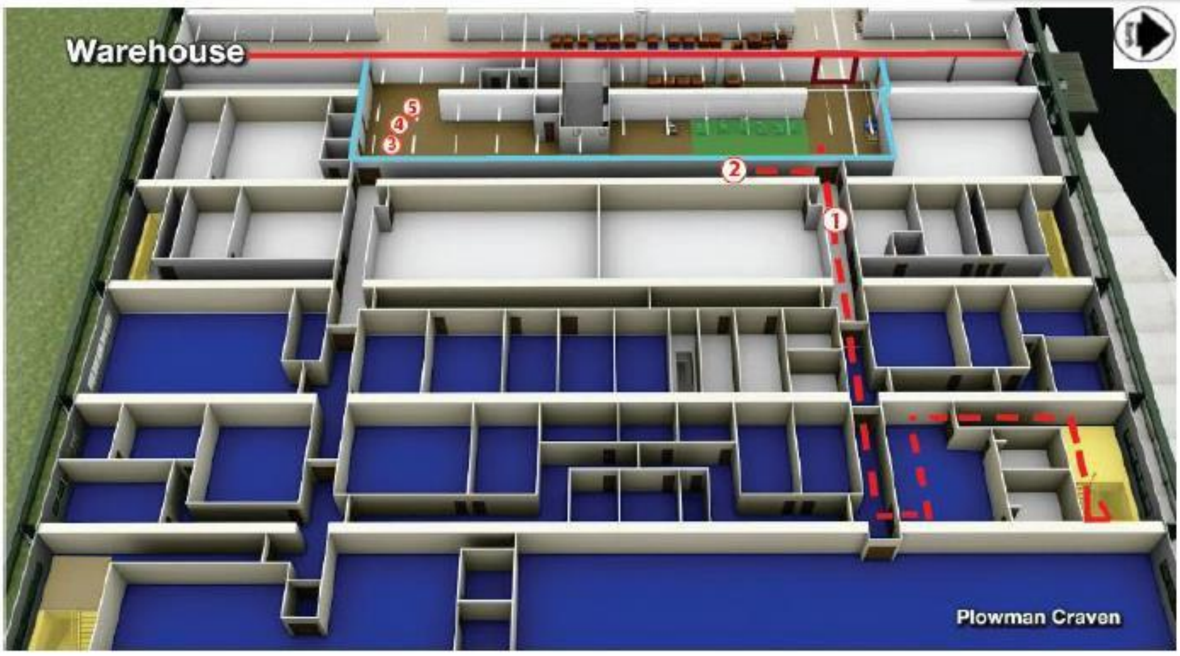
Crews are waiting for ET 2 on the stairs and they carry the casualty from Red 1 from the building. Immediate attempts are made to resuscitate the casualty in the vicinity of the entry point, initially byfirefighters.

19.31

An ambulance arrives and a paramedic assists with the resuscitation attempt.

19.32

Group Manager A arrives and after a short time is asked by IC3 to supervise the 2nd BA entry control point resourced by Hereford and Worcester Fire and Rescue Service (HWFRS) crews. Two crews fromHWFRS arrive with an accompanying fire cover officer and after a discussion with IC 3 begin to establish a second entry point (EP 2) at the fire escape previously identified on the road side of the building.



- - - Route of Emergency Team 2

① Full extent of Emergency Team 2's 45mm hose

② Approximate location where a crew member from Red 1 is found by Emergency Team 2

③, ④ & ⑤ denote the approximate positions of the three remaining members of Red 1 in the lift lobby

Hatched area (green) shows the approximate area where Red 1's branch was found

Figure 9 Showing location of all four casualties when located by Emergency Teams.

19.38

A three-person BA team (ET 3) enters the building through the original entry point (EP 1) with a briefto search the first floor office area to cover the front of the building to find the remaining three members of Red 1. They have a TIC and no firefighting media (as they are separated from the fire compartment). They search some of the offices on the left off the main corridor and note that there is not much smoke in the offices.

After searching the offices, ET 3 head towards the lift lobby area up the corridor and picking up ahose reel branch on the way. They encounter thick smoke and extreme heat on entering the lift lobby. They also hear the ADSUs and go left in their direction.

19.50

A four-person BA team (ET 4) is briefed with further new plans provided by the engineering manager, to lay a guide line to assist the rescue operation. During the briefing they realise theseplans are inaccurate and have to be annotated at the scene by the engineering manager.

ET 4 enter without firefighting media with a brief to collect a hose reel en-route. In the first floorcorridor they locate a hose reel, test it and find it ineffective. They continue to lay the guideline down the corridor towards the lift lobby.

19.52

Duty Group Manager B arrives and takes over as incident commander (IC4). He is accompanied by aBBC reporter and camera operator who have been working with him during the day.

19.57

The Chief Fire Officer (CFO) arrives, after speaking with IC3 and IC4 it is agreed he will deal withstrategic and organisational issues, whilst being kept informed of the operational aspects of theincident.

19.57

Water bowser crew requests an increase in the water pressure in the area. 13 minutes later IC4checks on progress and is informed that the request has been delayed, no postcode could be supplied and the request goes through to the wrong area.

19.58

IC 4 appoints a water sector with a Station Manager, who has just arrived, as functional sector commander. The plan is to utilise more appliances and crews, secure the borehole supply on site, which is capable of producing at least 35,000 litres a day and to secure a supply from the River Stourusing the WFRS High Volume Pump (HVP).

19.58

A crew go around to the south side of the building looking for alternative entry points and signs of their missing colleagues. They enter the building without BA through the staff entrance and go up tothe first floor. They initially encounter light white smoke as they search offices.

20.00 Assistance message from IC 4:

“*move to Command Level 4”*
(make pumps 12 plus further supporting officers).

20.00
The crew searching offices in the south east corner of the building exit by the staff entrance and re-enter through a fire exit further along the south side. They go up the stairs to the first floor – not encountering any significant smoke or heat until they open a set of double doors, when they encounter thick smoke, heat and hear ADSUs. Falling to their knees, they shout and try to see through the smoke with their torches but have to retreat back down the stairs due to the deteriorating conditions.

20.01
Assistance message from IC 4:

20.02
“*makes pumps 16”*.

BA main control is set up with the clocks synchronised and communication established withthe BA Entry Control Points.

20.02
The firefighter casualty from Red 1 rescued by ET 2 is taken to hospital – where he is formally pronounced dead.

20.02
The Group Manager (A) operating at ECP 2 and liaising with HWFRS is using the latest available plansto coordinate the use of guidelines. A HWFRS BA team (ET 5) enters the building with a hose reel to lay a guideline on the left hand wall.

The engineering manager and his 4x4 vehicle are commandeered by a WFRS firefighter to assist replenishing BA cylinder stocks. The engineering manager takes empty BA cylinders to Stratford-upon-Avon fire station for charging and leaves the site for approximately an hour.
ET 4 comes to the end of their guideline at the double doors leading to the lift lobby, where the flooris hot and there is a *“threshold of heat”.* They hear a loud bang in front of them and to their right; they believe the ceilings are starting to collapse within the lift lobby area.

The ceiling in the corridor is also in a state of collapse.

20.10

Water is being supplied from a large dam located outside ECP 1 which appliances are refilling via water shuttle from hydrants located in the area. The level in this dam is low and ET 4 is ordered to withdraw. They hear another BA team (ET 5) entering the building from another entrance. They areusing their own water supply from their appliance tanks.

Crews are having difficulty finding a hydrant with pressure and flow that allows them to get backbefore the dam supply is used. The use of 45mm jets has increased demand for water supplies.

ET 5 enters the corridor leading to the lift lobby and hears the sound of ADSUs coming from the liftlobby area. As they are laying their guideline on the left hand wall, they turn to their right in the direction of the ADSU's. The crew of ET 5 experience extremely hot temperatures when removing their gloves to tie off the guideline. They encounter another guideline which becomes entangled with theirs. They are low on air supply and pick up the guideline laid by ET4, exiting the building viaECP 1.

20.12

Warwickshire police arrive.

Two members of ET 5 re-enter ECP 2 to retrieve the hose reel. They get to the corridor leading to thelift lobby and encounter thick, black, smoke and temperature that has increased in the time they have been outside.

20.13

ET 5 is debriefed by the Group Manager (A) operating at ECP 2 and there is further discussion overthe accuracy of the plans supplied and annotated by the Engineering manager.

20.32

WFRS crew arrive and are tasked with marshalling appliances in a holding area. A further watercarrier arrives.

20.35

A Hydraulic Platform (HP) arrives.

20.36

A four-person BA team (ET 6) is briefed to enter ECP 2 to first floor and follow the sounds of the

ADSU's to locate the missing firefighters. They split into two teams, with two on the hose reel branchand two hose managing behind them. They are by the double doors to the lift lobby and hear an ADSU operating to their left. They look under the smoke layer and see torch lights in the distance.
Two of the crew head off down the left hand wall towards the torch lights and two stay behind themwith the hose reel.

20.37
The Deputy Chief Fire Officer (DCFO) arrives at the incident.

20.38
A four-person BA team (ET 7) is briefed to search and rescue Red 1 and enter via ECP 1 to the first floor using the guideline. They have a TIC with them and pick up the hose reel in the corridor. The BAteam reach the double doors to the lift lobby area. The hose reel and guideline are tangled and hamper their progress. They have to withdraw as their air supply is low.

20.51
Two members of ET 6 while crawling on their knees due to the heat, find two firefighters from Red 1. They are both on their backs and their torches are still on. Their BA gauges both read zero, their facemask seals are not broken and their helmets are on. There is no firefighting equipment or debrisnear them. ET 6 report back via radio to ECP 2 that two casualties have been located (Figure 10).

A four-person BA team (ET 8) is about to enter the building from ECP 1 when they hear the radio message. Having already handed in their tallies at ECP 1 they divert and enter instead through ECP 2to assist ET 6.

A third firefighter from ET 6 leaves the fully extended hose reel to help his colleagues with the casualties. They try to move them but are unable to do so. ET 6, experiencing intense heat and with their air supply running low have to withdraw from the warehouse without the casualties. On the way out of the lift lobby, they hear a loud crash and bang. The building is starting to collapse. On theway out, they meet ET 8 and tell them the casualties are at the end of the hose reel and that the building is failing.

20.54
Water carrier arrives.

ET 8 go to the end of the hose reel in the lift lobby in conditions of zero visibility. They hear ADSUs and drop to the floor to search. They sense things are falling all around them and after an "*almighty"*bang and crash, they are forced to withdraw.

Firefighters waiting for casualties in the staircase above ECP 2 hear a loud crash followed by a largeplume of black smoke entering the staircase.

The smoke outside is thicker and causing problems for some firefighters. The paint is blistering onthe cladding below the roof which is glowing red.

Figure 10 Showing the location of two casualties found by ET6.

21.00
The fire alarm system has been repeatedly reactivating throughout the incident. Following repeatedattempts to silence the alarm at the staff entrance, the engineering manager disconnects the battery. He notes that flames are now visible, having breached the south side of the building.

A four-person BA team (ET 9) accompanied by a two-person BA team (ET 10) consisting of two former members of ET 6 are briefed to enter ECP 2 for a further attempt to recover the casualties.

ET 10, with previous knowledge of the locations, are to guide ET 9 through the lift lobby doors andplace them on the left hand reference wall, then withdraw. ET 9 are briefed to recover the casualties.

21.05

The two teams go to the top of the staircase but are faced with conditions that are impossible to work safely in. There is thick black smoke and extreme heat causing ceiling tiles to fall. Thick blacktar is running down the walls. They withdraw.

21.10

Flames break through the roof.

21.13

DCFO takes over as incident commander (IC 5).

21.18

A High Volume Pumping (HVP) unit arrives.

21.22

Informative message from IC 5:

"*following dynamic risk assessment,*
based on information from BA crews, internal floors
and ceilings are in danger of collapse, all BA crews withdrawn."

BA team Red 1 – Activities

Prior to Red 1 entering they are given information about the suspected location of the fire, the location and distances to the fallen cables, partitions, the unknown triangular object, and the factthat conditions are very hot in the area around the triangular structure.

Red 1 enter at 1853 hours, their brief is to carry out a right hand search of the fire compartment andtackle the fire. IC 2 also gives them further objectives; to find a second entry point, identify any options for ventilating the building and feed this information back via the BAECP Officer. Their time of whistle is recorded as 1928 hours on the BA entry control board.

Red 2 see Red 1's hose reel go through the lift lobby entrance doors off to the right, and the Fire Investigation Team found the remains of their hose reel going right. The hose reel was found to be heading towards the gap in the four-hour wall. The amount of hose reel within the fire compartment(storage area) could not be determined due to sections of the hose reel up to the gap in the four- hour wall being burnt away.

Red 2 enter at 1907, approximately 14 minutes after Red 1. On entering the compartment throughthe double doors at the end of the corridor, Red 2 No. 1 hears Red 1 talking through the heat and smoke, ahead and off to the right.

N.B.:

The BRE report for WFRS states that "sometime between 1849 and 1915, the critical threshold was passed and the fire rapidly escalated, resulting in temperatures exceeding 6000C throughout the majority of the first floor storage area within six minutes." BRE modelling of the first floor storage area and lift lobby, during the rapidfire development, shows cooler air being drawn into the storage area creating an air in-track at lower levels. This would produce lower temperatures and improved visibility near the opening in the four-hour wall. However, at higher levels the temperature would increase and the visibility reduces.

Prior to BA emergency being called No. 1 of Red 2 is by the doorway to the corridor and hears Red 1 approximately 9m in front and 45^0 off to the right ("*roughly 30 feet in front and at an angle of about forty-five degrees to my right"), Nos.* 3 and 4 of Red 2 state they hear "*a crash, and a bang"* just before the BA emergency.

At the time of BA emergency Red 1 are at the same distance from Red 2, but start to move fromright to left ahead of them.

Whilst Red 2 are on the radio to the BAECP Officer Red 1 move further left so that they are now infront of Red 2, and by the time Red 2 come into the compartment to search for them Red 1 are totheir left ahead of them and moving further away.

As Red 2 move down the left hand wall towards the sounds from Red 1, they can hear rhythmic banging noises ahead of them. Red 2 also notice the heat increasing during this time. A short while later members of Red 2 hear "*someone or something kicking something like wood or a door. I thought they had gone into a room or something and this confused me even further."*

A member of Red 2, after sensing someone is close by, moves out from the left hand wall. With theirback to the wall (about 2m out from it), a member of Red 1 appears out of the smoke from the direction of the partition wall.

Whilst it is not definitively evidenced how far along the left hand wall the members of Red 2 were atthat time, the No.2 of the crew suggests they were 2 – 3 metres from the double doors on the left hand wall.

The crew member from Red 1 is placed onto the left hand wall. He then runs past Red 2 Nos. 3 and 4at the double doors and they lose sight of him in the smoke. He is found again approximately 6 minutes later in the corridor running adjacent to the lift lobby, 2 – 3 metres down the corridor. His face mask is on and also his helmet (although dislodged). His fire kit shows no signs of direct burningand his BA set personal line is stowed in its pouch.

Two other members of Red 1 are discovered by Emergency Team 6 (ET 6) further along the left handwall inside the lift lobby area, approximately 80 minutes later. Their masks and helmets are on and their BA gauges read zero. ET 6 is not able to recover the two team members of Red 1 and make a decision to withdraw.

The fire investigation found items belonging to all three remaining members of Red 1 them in this area, including three knives and a mobile phone. The fire investigation report noted "…*the blade of one of the knives appeared to be in the fully open position; the blade of a second knife appeared to be in a partially open position, suggesting that the firefighters may have been using the knives".*

Red 1 went on a right hand search into the fire compartment during the phase of the air *in track*. If they were in line against the wall they could have passed under the cable hazard encountered (and pulled down) by an earlier BA team, taking their hose reel with them. Progress may have been slowed by having to search the rooms off to their right, accounting for Red 2 being only a few metresbehind them.

They made further progress into the fire compartment where it is likely they became aware of therapid fire development and were forced to withdraw.

Red 1 team leader would have carried the hose reel branch and may have used it to protect the other members of the crew while they withdrew. It is likely that those at the back of the crew wouldthen have been leading the way out. During withdrawal they may have passed over the cable hazardwhich may have caused delay, entanglement or snagging of their hose reel. This could account for the hose reel branch location and the gap that developed between the crew members. Effectively the hose reel became snagged on the cables by passing under and then over.

It is possible that while withdrawing, the team leader of Red 1 went towards Red 2 thinking they were his team. The remaining members of Red 1 now go along the partition wall on their right (offfrom their reference wall). This wall leads them further into the lift area, which is where they are later located by ET 6. The lift motor room in this area had evidence of forced entry which would correspond to accounts of Red 2 hearing noises in this area.

Additional Information

The Incident Commander (IC) has the ultimate responsibility for the health and safety of crews at thescene of an incident. The role involves constantly taking in information from a range of sources, prioritising that information and making decisions based on it. These decisions are dependent on the quality, accuracy and availability of information.

Command Support

The sixth appliance in attendance should have been allocated to perform the command supportfunction but this did not happen due to it being utilised as a general fireground resource.

Briefing and de-briefing of BA crews

There was a lack of consistency in approach between commanders and BA crews to facilitate the exchange of important and relevant information. This was particularly evident at Entry Control Points although there were ad hoc briefing/debriefings taking place.

Handovers between Incident Commanders

There was a failure to document and time record the handover between ICs in the early phases upto the point when the Command Support function was fully established. There was also a lack of clear methodology in the handover.

Passing on of information by crews to the Incident Commander

There was a breakdown in communication between some areas of the fireground and those ICsmaking critical decisions. This resulted in important information not being passed on to those needing it e.g. the wall glowing red on the south side of the building was not passed back immediately to the IC on the opposite side of the building.

Accuracy of information

One of the main problems on the evening was the inaccuracy of the information presented, specifically, the layout of the warehouse beyond the first double doors and the location of the fire.The information presented to the ICs throughout the early phases of the incident was continually incorrect, even after revisions.

Fire safety and building construction knowledge

There was also a lack of understanding of modern methods of building construction by many of the operational crews.

Identification of sandwich panels

The presence of sandwich panels in the part of the building affected was not widely recognised atthe incident.

Firefighting Media

Firefighters at the incident used extended hose reels (up to 4 lengths) which was not usual practice.The decision to use extended hose reels at the incident was driven by a number of factors:

- previous success at the same location using this method
- problems associated with managing large diameter hose
- reducing air consumption en-route to the fire compartment
- misunderstanding of the fire size, location and conditions in the firecompartment

Breathing Apparatus (BA) Emergency

When the BA emergency was called there were two teams within the lift lobby area.

Fire and rescue service national guidance at the time states that "*When a distress signal is heard the team leaders of BA teams who have sufficient reserves of air are to direct their teams to investigate the source of the sound. Rendering assistance to a wearer in distress is to take precedence over the work in hand but regard must be had to keeping escape routes open and for rescues already being carried out. Once sufficient help is available any hose lines temporarily abandoned must be reinstated.*"

No ADSU was sounding at the time of the 'BA Emergency' message being sent back, meaning thatinitial emergency crews did not have an audible target to locate. National guidance under the heading of 'Lost in Smoke' also gives guidance that emergency crews could use to locate a BA team *"The branchman can always be found by following the appropriate hose line."* However, in this incident this would have taken emergency crews in the wrong direction and into potential danger (accelerating fire conditions and hanging cables).

The first firefighter from Red 1 encountered Red 2 in the lift lobby, but the firefighter who found him had a branch in one hand, and was therefore limited in his ability to restrain and guide him.

After the 'BA Emergency' was declared operational activities were entirely focused on rescue and the wider Incident Command considerations became secondary. Whilst an enhanced Incident Command structure was put in place at approximately 20.00 hours and water supplies were secured, no direct attack was made on the fire up until the time that all crews were withdrawn from the building.

After the 'BA Emergency' was called incident ground radio traffic increased significantly. This presented difficulties in crew to crew and crew to BAECP communication, which could have been eased by the use of additional channels.

Withdrawal from Building

Crews inside the lift lobby (adjacent to the fire compartment) were looking for signs and symptoms of backdraught and flashover, in accordance with their BA training, but the conditions they were encountering were not those that they had been taught to recognise.

Crew selection and availability

Initial resources on the incident ground were limited, which resulted in crews being combined from different stations and of mixed experience. One inexperienced firefighter was committed into the building as a member of Red 2.

Appendix 3

Background and briefing documents for Study 2, Case Study 2

Firefighter Injury Research Project

Phase 2 Case Study 2 – Balmoral Bar

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Introduction

At 00:38 on 12th July 2009 Lothian and Borders Fire and Rescue Service mobilised to a fire in a public bar at 178 Dalry Road, Edinburgh. The bar was in a building of four floors with a basement area where, in a room used for an office, the seat of the fire was to be found. The three floors above the bar contained a number of self-contained flats. Fire and smoke was spreading upwards towards the residential properties above the bar. The initial firefighting tactical plan prioritised the rescue of residents from the flats whilst at the same time, locating and extinguishing fire in the basement and ground floor bar.

During the firefighting operations, whilst attempting to exit the ground floor, a Firefighter entered a room off the public bar area and became trapped due to the door becoming jammed. While trapped in the room the Firefighter was instructed to activate his distress signal unit and a Breathing Apparatus emergency was declared by the Sector Commander. The attending firefighting crews made strenuous efforts to affect his rescue, at times placing their own lives at risk in an attempt to rescue the trapped firefighter. Tragically they were unable to reach him in sufficient time to save his life.

Fire Investigation that followed summarised that:

- The fire started within the basement office and spread to all fixtures and fittings.
- There was total involvement of all combustible materials within the office. It then spread out into the basement and to the underside of the timber joists and flooring of the ground floor.
- As the fire travelled through wall cavities, it affected residential properties on the first and second floors above the Balmoral Bar.
- There was severe fire and structural damage to the ground and basement floors of the building.
- Properties on the first floor were breached by fire causing damage to some of their rooms.
- The remaining properties suffered varying degrees of smoke and heat damage.
- Given the evidence of smoking within the office, witness accounts and published scientific literature, it is likely that the fire started as a result of the careless disposal of smoking materials.

The Building

To aid understanding and reflect building type and construction images have been copied and 'snipped' from openly accessible web sites and identified by number accordingly. A correspondinglist of references can be found at the rear of this case study. This was a traditionally built sandstone tenement building with a pitched timber and slated roof. Exact dimensions are indicated in the ground floor plan (Figure 3). An informative message estimated dimensions of 20 metres x 20 metres.

Figure 1. View of the building taken from Dalry Road – approximately 45^o to the corner of the building(Google Maps 2017).

Figure 1 better illustrates the dimensions of the bar. The longer frontage of the Bar is on Dalry Road and the shorter dimension is on Downfield Place. A single residency can be seen at ground floor level to the left of the Bar in Downing Place. There are five residences on each floor level above the

Bar. The yellow arrow corresponds with a common staircase that provides separate access to all flats. The rear of the building can also be accessed via this entrance. One of two emergency exits from the bar area also opens into this common area. The second emergency exit from the Bar opensinto a rear garden, the door is situated immediately next to the toilets at the rear right of the bar (see Figure 3). The white arrow indicates the location of a basement access hatch This item has been removed entrance.

Figure 2. Aerial image of the building showing the full footprint and dimensions with the re-furbished barfrontages clearly indicated by their black painted finish (Google Maps 2017).

Figure 2 provides a more complete aerial view of the building footprint. Access to what is also described as a 'common drying green' at the rear of the building can also be made from a common staircase entrance and lobby at 172 Dalry Road which is the adjacent building to the right.

The Bar Area

The layout of the bar included fixed seating areas, bar area, fast food preparation area and toilets to the rear. Access to the bar was via a door from Dalry Road indicated by the red arrow. Access to the basement is via a stairway situated to the left of the bar (figure 3). The basement was used to store beer kegs, carbon dioxide cylinders, coolers and other supplies used in the licenced trade. There was also general storage of seasonal items, furnishings and promotional materials.

Located at the rear of the basement was a room used as an office where the administration of the business was undertaken. There were various electrical items such as a computer, CCTV systems, and safes used to store cash. There was also a fitted, lockable timber cupboard used to store bottles of spirits. The floor above the office was multi-layered consisting of a reinforced concrete slab resting on timber joists. All other floors throughout the building were constructed of timber boards over timber joists.

Figure 3. Floor plan of the Balmoral Bar at the time of the incident (SFRS 2016).

The Incident			
00:38 Lothian and Borders Fire and Rescue Service (LBFRS) received the first of seven 999 calls. The caller stated that the pub [the Balmoral Bar] was on fire. This was confirmed by a telephone call from Lothian & Borders Police (LBP) who had received a call from the bar staff stating that 'the place was up in flames'. Three pumping appliances and a turntable ladder (TTL) are mobilised to the incident as the pre-determined response (call signs 301, 302 and 311 and TTL 303). In all 16 personnel.	**Cat A Code**	**Cat B Code**	**Cat C Code**
00:42 The first two pumps (301 & 302) and TTL in attendance. On arrival, the main entrance door is open and crews could see a well-developed fire with thick smoke issuing from the entrance door. Several occupants could be seen at the windows of the flats above the bar. The Incident Commander (IC), made contact with the bar manager and was told the fire was in the basement office at the rear of the bar. He also provided directions for access to the basement. The TTL was positioned at the corner of Dalry Rd and Downfield Pl and pitched to effect rescue from the flats above the bar. The IC tasks a WM with the evacuation of the flats in Downfield Place. The weather conditions at this time are dry with a light wind.			
00:45 311 is now in attendance. Crews commence to run out a hose reel but given the location of the fire the IC has this changed to a 45mm line of hose. A breathing apparatus entry control point (ECP 1) is established at the front of the building. The first two BA Teams make an entry, two Firefighters (Ffs) (BAT1) are told how to access the basement from behind the bar and using the 45mm hose tasked with locating and extinguishing the fire. One of the members of this team is a Probationer. Another team of two Ffs (BAT2) are tasked with hose management and have a Thermal Image Camera (TIC) with them. There is almost zero visibility within the bar area. The temperature is moderate but increases as they progress behind the bar to the basement. From a second entry control point (ECP 2), a third team of two Ffs (BAT3) were also deployed to search the ground floor flat on Downfield Pl and the flats above.			

<u>00:47</u> First informative: *"….Fire within basement, at work with 6BA and 1 line of hose, Offensive mode."* This message was quickly followed by another message stating *"Stage 2 Entry Control now in operation."*			
<u>00:49</u> First rescue effected (child) using short extension ladder in Downfield Pl.			
<u>00:50</u> Assistance message: *"…make pumps four".* Two adults rescued by TTL at Downfield Pl. At the same time BAT3 are progressing to the upper floors using the common stairway but because it is heavily smoke logged they are making contact with and reassuring residents before they can be safely escorted from the building.			
<u>00:52</u> Hampered by thick smoke and significant heat as well as the confined space behind the bar, BA Teams 1 and 2 are experiencing difficulties in locating the stairs to the basement. The smoke is that thick that their facemasks are 'sooting' and they can't see the display on the TIC. BAT2 exit the Balmoral Bar to obtain more information on how to access the stairs leading to the basement. BAT2 go back into the building and pass this information to BAT1.			
<u>00:54</u> Three more people rescued from flats in Downfield Pl.			
<u>00:55</u> Assistance message: *"…make pumps five".* BAT1 & 2 find the basement stairs, BAT1 descends with the jet and encounter a noticeable rise in temperature. Remaining at the doorway to the stairs BAT2 assist with hose management ensuring that BAT1 can make progress in the basement. When BAT1 leaves the stairwell and enters the basement they encounter another rise in temperature. They pulse firefighting water into the ceiling but have not located the fire. After a short while they check their gauges and due to low cylinder contents, leaving their jet approximately two metres into the basement withdraw. At the top of the basement stairs they link up with BAT2 and both teams exit the bar at approximately 01:07 and are debriefed by IC. They have been inside the bar for about 22 minutes.			

00:59 Three more people rescued from flats in Downfield Pl are walked down the TTL. With the first 'make-up' appliance in attendance the IC takes the crew to the basement delivery hatch in Downfield Pl and informs them to open it to see if it can be used for entry into the basement.			
01:07 BAT1 & 2 exit the bar and report to ECP 1 where they are debriefed by the IC. BA Teams 1 and 2 change the cylinders on their BA sets ready to be redeployed. During this period, all the BA wearers remove their flash hoods and open their tunics. Water is provided and consumed by all four BA Wearers. BAT3 exit and report to ECP 2.			
01:09 Having set up a covering jet, the IC and BAT4 investigate the pavement delivery hatch in Downfield Place. When the hatch is opened volumes of dark grey smoke start issuing and the IC decides it is not a suitable access point. The hatch is left open. The IC takes BAT4 to ECP1 at the front of the bar and instead briefs them to follow the line of hose run out by BAT1 to the bottom of the basement stairs and continue with firefighting. They enter the bar with a high pressure hose reel jet (HRJ) for protection. When they locate the branch in the basement they advance but they too still do not locate the seat of fire. BAT1 & 2 have by now changed the cylinders on their BA sets ready for redeployment. Whilst doing so they take advantage of the opportunity to remove their flash hoods, open their tunics, and drink some water. A senior officer has also arrived and reported to the incident control point and indicated he would assume command after liaising with the current IC. The change of IC is confirmed in an informative message at 01:14. On taking over the initial IC becomes Sector 1 Commander (SC1).			
01:12 Two more people rescued in Downfield Place which is by now designated Sector 2.			
01:13 BAT1 report to ECP1 to be re-committed into the incident. SC1 asks if the team are ok to go back in, to which the team members give a thumbs-up sign. SC1 then briefs BAT1 to proceed to the basement to continue firefighting.			

<u>01:14</u> Prior to BAT1 completing their 'start-up' routines at the ECP, BAT4 progress down the basement stair and commence gas cooling for three to four minutes. The team leader of BAT4 observes an orange glow from his position.			
<u>01:16</u> BAT1 have been outside the bar for approximately 10 minutes. Before entering they are asked by SC1 if they are *'good to go'*. When they confirm that they are ready to be redeployed they are briefed to retrace their steps to the basement, locate the branch and continue firefighting. They then re-enter the bar taking a Hose Reel Jet for protection.			
<u>01:18</u> SC1 takes BAT2 around to Sector 2 to inspect the beer delivery hatch. SC1 again considers this as a means of entry. BAT2 is unsure about where the delivery hatch leads or the depth of descent and suggest that they are recommitted through the front door. SC1 and BAT2 proceed back to ECP1. The delivery hatch is left open.			
<u>01:19</u> SC1 instructs an available Crew Manager (CM) to break all the windows at the front of the bar. Before the CM proceeds to do so SC1 contacts all BA teams inside the Bar via radio to indicate to the BA Teams that the windows are about to be smashed and to ensure they are on a Branch. BAT1 acknowledge receipt of this message, BAT4 is still at the branch in the basement and receive the message but do not respond.			
<u>01:20</u> The ventilation CM asks SC1 to confirm no one is working near the windows and on having this confirmed begins to break the windows either side of the entrance door. After the bar windows are smashed a member of BAT4 commented that the temperature inside the bar *'did rocket up'*. BAT4 makes their way out of the basement and come across BAT1 at the foot of the stairs. A short briefing is carried out between BAT4 and BAT1. BAT4 confirm the fire has not been located. BAT1 continue towards the branch and due to low cylinder contents BAT4 makes their way out of the bar.			
<u>01:21</u> BAT2 are once again re-committed, they are briefed to proceed to the basement to assist BAT1 in fighting the fire.			

A new BA team BAT5 are briefed to enter the building to search the flats above the Bar, they enter via ECP2 at Sector 2.			
01:22 BAT5 reach Flat 2 on the second floor.			
01:23 BAT3 are once again briefed to proceed to the pavement delivery hatch. Although the seat of fire is not known, they are told to deliver water into the basement via a line of hose which they do for approximately ten minutes.			
01:25 BAT4 exit the Bar and report to ECP1.			
01:27 Concerned by residents being trapped in the flats above the fire and the volumes of smoke issuing from the Bar the IC sends a further assistance message making pumps 7 for additional BA wearers. With the heat now unbearable BAT1 leave the basement. They meet BAT2 on the ground floor at the end of the bar and reiterate that they are withdrawing due to the effects of the heat. Visibility on the ground floor at this time is almost zero. BAT1 then pass BAT2 and the BAT2 team leader shouts to BAT1 to follow the hose out. Leading BAT1 out the Probationer has contact with the 45 mm hose they laid earlier with his left hand. He turned to his No.2 and asked him if he was still following the hose which he confirmed. When they reach the hatch at the end of the bar, still following the line of hose the leader of BAT1 turns right aware that his team member is behind him. He does not discuss the change of direction because they have already agreed to follow their hose back out of the building and makes his exit assuming his No.2 is behind him. On the floor at the hatch leading into the bar there are three lines of hose reel and the line of 45mm hose. At this stage of A BA Emergency Team is requested by SC1, and two Ffs get rigged in BA and wait by the ECP1. Back in the bar, BAT2 comes across BAT1 ascending the stairs from the basement. BAT1 could be heard shouting to each other about the heat in the basement, they continue up the stairs and pass BAT2. As they do a member of BAT2 hears the Ff at the rear of BAT1 say *"I'm going outside I'm ****** with the heat."* Although this Ff is behind the team leader he is in touch with him.			

<u>01:29</u> The team leader of BAT1 emerges from the Bar alone. Asked by SC1 where his No.2 is he replies *'he's right behind me'*. Seeing that he isn't SC1 tells him to go and get him and BAT1 team leader re-enters the bar to search for him. Immediately, SC1 contacts the missing Ff on the radio and is told *'I'll be there in a minute Boss; I think I'm stuck in a toilet.'* On hearing this SC1 tries to stop the BAT1 team leader first by crawling in after him but without breathing apparatus has exit almost immediately he then shouted but couldn't stop him. At this time BAT2 reaches the top of the stairs and attempt to descend but are unable to do so because of the heat. Instead they spray water down the stairwell in an attempt to cool the area which has no effect and they decide to exit the bar.			
<u>01:31</u> SC1 contacts the missing Ff via radio who is heard saying over the radio *'I'm still stuck, I'm still stuck'* on hearing this SC1 asks if he can feel any hose at his feet and is told *"No I can't…I can't feel it."* On hearing this SC1 instructs him to activate his Automatic Distress Signal Unit (ADSU) and tells him that other BA wearers are coming to get him out but gets no response. At the hatch at the end of the bar BAT2 come across the team leader of BAT1 who explains that his No.2 had not come out of the bar. BAT2 confirm they heard his conversation with SC1 over their radio. The team leader of BAT2 then contacts the missing Ff asking him where he is and is told *"I've turned left at the end of the bar instead of right, I'm in a toilet up there somewhere."* Having by now heard SC1 give the instruction to activate the ADSU all three proceed to search for the missing member of BAT1. Without a Hose Reel for protection and with the heat becoming more intense and not having heard an ADSU, they have to stop and withdraw from the Bar.			
<u>01:33</u> BAT2 and the team leader of BAT1 exit the bar. On doing so they set about servicing their BA sets to make themselves available for another entry.			
<u>01:34</u> SC1 declares a BA Emergency. BAT5 discover two adults and a young child in distress. The child is given oxygen and having been left with the family the No.2 of BAT5 requests a ladder to be pitched to the rear of the building to affect rescue. A 10.5m ladder is used to remove the family from the building. Whilst this is taking place the team leader makes his way to an adjacent flat to investigate a banging sound which turns out to be a CM at the head of the TTL tapping on the window to attract the attention of any occupants. The leader of BAT5 then searches the remainder of the flat.			

<u>The Search and Rescue</u>			
<u>01:36</u> After being briefed by SC1, without equipment or any means of firefighting the first BA Emergency Team (ET1) is committed to follow the charged line of hose into the bar to search for the missing Ff. The likely location was in the toilets at the rear of the bar.			
<u>01:37</u> The BA Entry Control Officer at EP1 announces the missing Ff has 15 minutes of air until his 'time of whistle'. Outside the bar BAT4 have a line of charged hose and are instructed to provide cover for the BA Emergency Teams. They have been told to direct their jet through the broken windows towards the rear of the bar and toilets.			
<u>01:39</u> Having quickly serviced their sets BAT2 returned to ECP1 where, also without equipment of means of firefighting, they were committed for a third time as ET2 into the bar to assist ET1. Both teams were told to proceed to the toilets at the rear right hand side of the bar, past the gaming machines which was the last known location of the missing Ff.			
<u>01:40</u> Work to remove the wooden panelling under the windows to the right-hand side of the bar entrance begins in an attempt to improve conditions inside the building.			
<u>01:41</u> ET1 meet ET2 at the hatch area of the bar. They confirm where they believe the location of the toilet is. Both teams stop speaking and hold their breath in an attempt to hear the ADSU or any sound of the missing Ff moving about. Hearing nothing passing the gaming machines they proceed along the left hand wall towards the rear of the bar and toilets. Outside, BAT3 are relocated from the basement hatch and moved just inside the bar entrance door and told to direct their jet at the rear of the bar and towards the toilets. At the same time BAT4 have also re-entered the bar with instructions to go to the basement and continue firefighting. They are able to follow the original hose line and descend the basement stairs.			

<u>01:42</u> ET1 quickly comes upon a door leading to the ladies toilet and call to ET2. Almost simultaneously, to their right, ET2 locate what they believe to be a door leading to the mens toilets and the team leader attempts to open it, whilst there is slight movement something on the other side of the door is restricting it. Both teams are constantly shouting out to the missing Ff but without reply, neither team are able to hear an ADSU sounding. During yet another unsuccessful attempt to gain entry to the toilet the team leader of ET2 feels the floor sag slightly beneath his feet and at the same time the No.2 of ET1 shouts *"The floor is going to go."* Pushing harder on the toilet door team leader from ET2 detects some movement but almost simultaneously the floor collapses underneath him and he falls through becoming engulfed in flames. As he falls he is able to grab his BA partner's leg who quickly reacts and helps him scramble out of the hole. Briefly they are separated but quickly locate each other however, now disorientated they do not know which direction to go to reach safety. ET1 are outside the ladies toilet door with a wall to their left when the floor collapses and they experience a significant increase in heat. They too are disorientated but continue to move away in an attempt to get to safety. They quickly make their way out of the bar keeping as close to the wall as possible. Once at the front of the bar area, the floor became more solid and following the hose they were able to reach the front door. They describe how traversing the floor was like walking on something soft, a *"hot wet sponge".* When BAT3 heard the noise of the floor collapsing they moved outside but continued to direct their jet into the bar to knock back the flames rolling across the ceiling hitting ET2 with the water stream. ET2 use this to guide them to the entrance and are able to exit the bar.			
<u>01:45</u> At the rear of the bar in Sector 3 the emergency exit door has been located.			
<u>01:46</u> BAT3 report to EC1, two other firefighters then direct a jet through the bar window as the severity of the fire increases.			
<u>01:47</u> A Watch Manager is appointed to the role of Search Coordinator (SCo).			

01:48 ET1 and ET2 exit the bar area. Both teams reported to the IC and SC that the floor had collapsed and that it was unsafe to commit BA crews. BA Team 4 is still in the basement and has located the branch but do not find the fire. The temperature is significantly hotter and they decide to retreat because they are concerned that the fire may be affecting the stairs into the basement. BAT6 are briefed to enter the bar and take a left hand route on the ground floor to try to proceed to the basement and commence firefighting with the 45mm hose. Very quickly afterwards, concerned that the missing Firefighter may have fallen through the floor, BAT7 are briefed to make their way to the basement to commence a search.			

01:51 BA Team 4 exit the bar.			
01:52 The calculated 'Time of Whistle' of the missing Firefighter.			
01:54 BAT6 and BAT7 make their entry, BAT6 enter with a Hose Reel and meet BAT4 on their way out of the bar. BAT6 reach the end of the bar and the gaming machines and try to progress toward the rear of the pub. They are uncertain of the condition of the floor as it feels unstable. They are unable to move very far into the rear of the pub but attack the fire above them. On the right hand side of the bar, BAT7 also encounters the unstable floor. They cannot progress very far and also attack the fire from their position. A further assistance message is sent to 'make pumps nine'. In fire control, operators are unclear as to how many additional appliances are required as an additional appliance was mobilised when the BA Emergency was declared. They make a phone call to the Command Support Unit to clarify exactly how many appliances are required and are told the last assistance message did not include the appliance mobilised for the BA Emergency.			
02:01 BAT6 locate a fire in the basement and commence firefighting.			
02:02 BAT7 proceed to the basement after feeding hose to BAT6. The team leader of BAT7 notices a rise in temperature and humidity.			

<u>02:05</u> Another resident is rescued from the third floor at Sector 3. A crew of four were required to pitch a 135m Ladder to effect the rescue of a woman making a total of 15 rescues.			
<u>02:09</u> By now the emergency exit door in Sector 3 has been opened and an internal door leading into the bar can also be seen to be slightly open. The window to the left of the exit door has also been identified as an alternative entry point. However, it is protected by several layers of security including metal bars, heavy gauge wire mesh and a heavy steel plate.			
<u>02:10</u> Concerned about the high turnover of BA wearers. The IC makes decides to make pumps 11 for more BA resources.			

<u>02:12</u> BAT10 are briefed to enter and take a left hand route to find the Gents toilets. As they do they can see flames coming through the floor but find they are unable to get past the fire door because of the floor collapse. An ADSU could be heard from inside. As BAT10 come out an angle grinder was being used on the security measures but it is quickly apparent that heavier equipment was required to gain access through the window.			
<u>02:15</u> The OC identifies that the initial IC, now the sector 1 commander, has been working at the main scene of operations for some time and takes the decision to replace him. The OC then instructs the Logistics Officer to assume the role of sector 1 commander.			
<u>02:20</u> Another adult male resident is rescued from Sector 2 using the Turntable Ladder (making 16). A further informative message is sent stating the ACFO is now the IC. He then appoints the previous IC Operations Commander (OC). The new IC also requests the attendance of the Chief Fire Officer.			

<u>02:26</u> A Stihl saw is used to remove the security from the window. Cutting through the security measures was extremely difficult. Crews then found they still had to cut through layers of plywood, plasterboard, tiles and timber framing. In total this took approximately 27 minutes. Prior to this BAT10 had been briefed to enter and search the toilet as soon as there is an opening. When they do, the team leader encounters the missing Firefighter immediately underneath the window opening, they can also see the red lights of his ADSU and hear it sounding. Conditions inside the toilet are precarious, with significant heat, heavy smoke logging and the collapsed floor. The No.2 enters the toilet to assist but movement is seriously restricted and they struggle to affect the removal of their casualty. While attempting to recover the casualty a foot of the BAT10 team leader drops through the fire-damaged floor. Only a small section of floor remains intact around the area where the missing Firefighter is located.			
<u>03:01</u> BAT10 are committed via the bar toilet window, where they describe conditions as being hot with zero visibility. They immediately discover the missing firefighter beneath the window.			
<u>03:05</u> BAT10 must come out without their casualty due to the fatigue of attempting to get him out. They have removed a sink to create space and assist with access.			

BAT12 enter the toilet and recover the casualty BAT10 assist from outside thewindow. Outside, Paramedics receive the casualty and he is very quickly taken to their waiting ambulance. During this journey, still sounding, the ADSU is removed from the BA Set.			
<u>03:21</u> The casualty is pronounced dead at Edinburgh Royal Infirmary.			

Appendix 4

The Bristol Online Surveys questionnaire as viewed by participants.

Improving Firefighter Safety - Injury andDecisions

Thank you for participating in this survey. The informationyou provide will improve understanding of Firefighter decision making in those rare situations that result in injury. The overall aim of the research behind this survey is to reduce Firefighter injury, sharing your experiences will make a significant contribution to this aim.

Participation in the project is entirely voluntary; you can withdraw from the survey atany point, without giving a reason for doing so. Please be assured that the **informationyou provide will remain strictly confidential and anonymous**. Responses will be reported so that no individual or Fire and Rescue Service will be identifiable in any publication presenting the results of the survey.

By responding to, and completing the questionnaire, your consent to take part in the study is assumed. It is also assumed that you agree to the use of anonymised quotes in publications. If you would like to have further information about the confidential nature of you participation in the project, please contact the researcher via email (goughw@uni.coventry.ac.uk).

Many of the responses you will be asked to give can be selected from multiple choice or YES/NO options but some do require a bit of explanation. To help, you can save your placeand come back to the survey to continue. You will also be able to see how far you have progressed.

Before continuing it's important that you give some thought to the likelihood that in thinking about the circumstances of your operational injury you may invoke memories and emotions that could lead to distress. Whilst I'm sure your service has

a policy for ensuring support is available it's important that you confirm you are familiar with these arrangements should you need to use them.

1. Please select the choice below that applies to you. *Required*

- I am familiar with my service arrangements for seeking help and support in the eventof traumatic or emotional response to participating in this survey.
- I am no longer serving with a Fire and Rescue Service but I am familiar with arrangements I can make for seeking help and support in the event of traumatic oremotional response to participating in this survey.
- I am not familiar with any arrangements I can make for seeking help and support inthe event of traumatic or emotional response to participating in this survey.

About YOU

2. Gender *Required*

Please select exactly 1 answer(s).

- [ ] Male
- [ ] Female

3.

Please enter a whole number (integer).

Please make sure the number is between 18 and 65.

Age at time of the INJURY *Required*

4. Length of Service at time of the INJURY *Required*

Please enter a whole number (integer).

Please make sure the number is between 1 and 45.

5. What was your role map at the time of the INJURY? *Required*

- Firefighter in development
- Firefighter (competent)
- Crew Manager
- Watch Manager Flexible
- Duty Role

6. Which of the following best describes the Duty System you were working at the time ofyour INJURY? *Required*

- Whole Time
- Retained Duty System
- On Call
- Flexible Duty System
- Day Crew
- Other

6.a. If you selected Other, please specify:

Your answer should be no more than 1200 characters long.

About your INJURY

7. Can you remember the date of your injury? *Required*

- YES
- NO

7.a. What was the date of the INJURY? *Required*

Dates need to be in the format 'DD/MM/YYYY', for example 27/03/1980.

(dd/mm/yyyy)

7.b. If you can't remember exactly, what was the approximate date? e.g. June 2015.

Your answer should be no more than 50 characters long.

8. What type of INCIDENT were you attending? *Required*

- Fire
- Road Traffic Collision
- Water Rescue/Recovery
- Hazardous Materials/Substance
- Animal
- Other type of Special Service.

9. Can you remember the time of your injury?

- YES
- NO

9.a. Time of the INJURY (if known)

Times need to be in the format 'HH:MM', for example 15:43.

(hh:mm)

9.b. If you can't remember exactly, was it

- 08:00 - 19:59
- 20:00 - 07:59

10. Severity of INJURY: For the purpose of this study, severity of injury isonly being measured by the effect it had on your ability to return to duty in terms of absence from work. *Required*

- No time loss Less
- than 7 days7 days
- or more

11. In the box below describe where you were at the time of your INJURY. *Required*

Your answer should be no more than 1200 characters long.

12. In the box below describe what you were doing when you were injured. *Required*

Your answer should be no more than 1200 characters long.

13. Were you working under direct supervision at the time of your injury? *Required*

- Yes
- No

14. What was your specific **goal/objective** at the time you were injured? *Required*

Your answer should be no more than 1200 characters long.

About the DECISION that resulted in your injury

15. Was there any time pressure involved at the time of your decision?

- Yes
- No

Required

16. At the time, did your injury result from: *Required*

- A choice you made yourself
- A choice somebody else made

16.a. If the choice was made by somebody else, were you in any wayinvolved in the decision making process?

- Yes
- No

About your APPROACH when making or participating inthe decision and choices that resulted in your injury.

17. What kind of things did you look for when you made your decision?
 Required

Your answer should be no more than 1200 characters long.

18. What prompted you to make your decision? *Required*

Your answer should be no more than 1200 characters long.

19. How did you know when to make the decision? *Required*

Your answer should be no more than 1200 characters long.

20. Were you expecting to have to make this specific decision? *Required*

- YES
- NO

About the INFORMATION you used to make your decision.

21. What information did you have available to you at the time of your decision? *Required*

Your answer should be no more than 1200 characters long.

22. What information did you use in making this decision, how did you getit? *Required*

Your answer should be no more than 1200 characters long.

23. How timely was the information you obtained? *Required*

- More or less instantaneous
- Less than 5 minutes
- More than 5 Minutes
- Took quite some time

24. Did you use all of the information available to you when made yourdecision? *Required*

- YES
- NO

25. Was there any additional information that you might have used toassist in making your decision? *Required*

- ○ YES
- ○ NO

26. What was the most important or influential piece of information you used to make your decision? *Required*

Your answer should be no more than 1200 characters long.

27. Did you consult with others whilst you were assessing the situation? *Required*

- ○ YES
- ○ NO

28. Were there any other alternatives available to you other than decisionyou made? *Required*

- ○ YES
- ○ NO

28.a. What other courses of action were considered or were available?

Your answer should be no more than 1200 characters long.

28.b. How was the option you took selected and any alternative rejected?

Your answer should be no more than 1200 characters long.

29. If the choice you made was shared with others, how was it shared?

Your answer should be no more than 1200 characters long.

30. Did you follow any recognised process to make the selection?
Optional

- YES
- NO

30.a. What was it?

31. Was there any stage during the decision making process in which youfound it difficult to process and think about the information available?
Required

- YES
- NO

31.a. Are you able to explain why this was?

About the way you RECOGNISED what to do.

32. At the time did you recall a previous experience in which you've made a similar decision? *Required*

- YES
- NO

32.a. Can you describe it?

Your answer should be no more than 1200 characters long.

33. Did this decision fit a standard scenario, had you been trained for dealing with the specific situation? *Required*

- YES
- NO

33.a. What specific training/experience was necessary or helpful in making this decision?

Your answer should be no more than 1200 characters long.

34. Did you imagine the possible outcomes of this decision, the way things would unfold? *Required*

About things that may have INFLUENCED you at the time

35. Did you at any time feel like you were out of your depth, that you didn't have sufficient knowledge for the decisions and actions you were taking? *Required*

- YES
- NO

36. Did you at any time feel like you didn't have sufficient skill for the decisions and actions you were taking? *Required*

- YES
- NO

36.a. What training/knowledge or information might have helped you in making this decision? *Required*

Your answer should be no more than 1200 characters long.

REFLECTING on your decision

37. In the same circumstances would you do the same thing(s) again? *Required*

- Yes
- No

38. At that moment in time, were you expecting to make such a decision? *Required*

- YES
- NO

38.a. Why was this?

Your answer should be no more than 1200 characters long.

39. Are there circumstances where your decision may have turned outdifferently? *Required*

- YES
- NO

39.a. What would have changed the outcome of your decision?

Your answer should be no more than 600 characters long.

40. How long did it take for you to actually make the decision, did you getstraight to it?

 Required

- Pretty much instantaneously
- I thought about it for awhile but not for long
- I took some time to weigh my options
- I waited for a second opinion

Unfortunately, in these circumstances you will not be able to participate any further in the Firefighter Injury Survey.

The University is grateful for your willingness to participatebut has to put your health and well being first and would hope you understand why this measure is necessary. If you would like to discuss this further please contact the researcher directly:

goughw@uni.coventry.ac.uk

You have completed the survey. Thank you for giving your time and participating in research designed to improve the safety and decision making of Firefighters. If you would like to discuss this further with the researcher please contact Bill Gough: goughw@uni.coventry.ac.uk

Having now completed this survey if you would prefer to discuss the project directly with a member of the Health and Life Sciences faculty, the Director of Studies responsible for the research project is Dr Gail Steptoe-warren, she can be contacted using: hsx566@coventry.ac.uk

Alternatively, should you wish to discuss the project directly with a more senior member of the University the Vice Chancellor, Professor Ian Marshall can be contacted via: csx300@coventry.ac

Appendix 5

Sequence of adjustments made to create nanocode statements and amended category labelling included in the Excel worksheet provided for Case Study 1.

Selected Examples* from HFACS Level 1 Unsafe Acts	Adapted Nanocode Statements
Skill Based Errors	
Breakdown in Visual Scan	
Inadvertent use of flight controls	
Poor technique/airmanship	Incorrect use of equipment
Over-controlled the aircraft	Poor technique
Omitted checklist item	
Omitted step in procedure	Omitted part of procedure
Over-reliance on automation	
Failed to prioritise attention	Failed to prioritise attention
Task overload	
Negative habit	
Failure to see and avoid	
Distraction	Distraction
Decision Errors	
Inappropriate manoeuvre/procedure	Adopted incorrect procedure
Inadequate knowledge of systems, procedures	Inadequate risk assessment
Exceeded ability	Exceeded ability
	Inappropriate action
Wrong response to emergency	Unsuitable choice of action
Perceptual Errors	
Due to visual illusion	Visual impairment/illusion
Due to spatial disorientation/vertigo	Spatial disorientation
Due to misjudged distance, altitude, airspeed, clearance	Misjudged distance/angle/speed/size
Routine Violations	
Inadequate briefing for flight	Failed to properly prepare for the task(s)
Failed to use ATC radar advisories	
Flew and unauthorised approach	Adoption of unauthorised procedure
Violated training rules	Violated training/guidance note
Filed VFR in marginal weather conditions	
Failed to comply with departmental manuals	Failed to adhere to equipment use/specification
Violation of orders, regulations, SOP's	Failed to adhere to standard operating procedures

Failed to inspect aircraft after in-flight caution light	
	Over aggressive use of equipment
	Not competent for the task(s)
Exceptional Violation	
Performance of unauthorised acrobatic manoeuvre	Intentionally exceeded the guidance of the standard operating procedure
Improper take-off technique	
Failed to obtain valid weather brief	
Exceeded limits of aircraft	Intentionally exceeded the limits of the equipment
Failed to complete performance computations for flight	
Accepted unnecessary hazard	
Not current/qualified for flight	
Unathorised low-altitude canyon running	

Selected Examples from HFACS Level 2 Preconditions of Unsafe Acts	Adapted Nonocode Statements
Condition of Operator	
Adverse Mental States	
Loss of situational awareness	Loss of situational awareness
Complacency	Complacency
Stress	
Overconfidence	
Poor flight vigilance	
Get-home-itis	Finish the job itis
Mental fatigue	Mental fatigue (disorientation)
Circadian dysrhythmia	
Channelised attention	Channelised attention (tunnel view)
Distraction	Distraction
	Haste
	Misplaced Motivation
Task Saturation	Task saturation
Alertness	
Adverse Physiological States	
Medical illness	Medical Illness
Hypoxia	
Physical fatigue	Fatigue - Overworked
Intoxication	Impaired physiological state (drugs or alcohol induced)
Motion Sickness	
Effects of OTC medications	

	Fatigue - Heat
Physical/Mental Limitations	
Visual limitations	Visual limitation
Insufficient reaction time	Inadequate reaction time
Information overload	
Inadequate experience for complexity of situation	
Incompatible physical capabilities	Incompatible physical capability
Lack of aptitude to fly	
Lack of sensory input	
	Incompatible intelligence/aptitude
Personnel Factors	
Crew Resource Management	
Failed to conduct adequate brief	Inadequate briefing/tasking
Lack of teamwork	
Lack of assertiveness	
Poor communication/coordination within and between aircraft ATC etc	Communication/Coordination
Misinterpretation of traffic calls	Misinterpretation of Communication
Failure of leadership	Failure of Leadership
	Failed to use all available resources
	Providing back - up
Personal Readiness	
Failure to adhere to crew rest requirements	Inadequate resting
Inadequate training	
Self-medicating	Self-medicating
Overexertion while off duty	Sub standard Physical Condition
Poor dietry practices	
Pattern of poor risk judgement	
	Affected by substance or hangover
Environmental Factors	
Physical Environment	
Weather	Weather Conditions (wind, snow, rain etc)
Altitude	
Terrain	Ground Conditions
Lighting	Light Intensity
Vibration	
Toxins in the cockpit	
	Heat/Cold Stress influence on performance
	Impeded movement due to obstacle/confined space
	Climate (temperature)

	Obscured Vision (other than smoke, such as fog, snow rain)
	Noise Interference
	Darkness
	Smoke
Technological Environment	
Equipment controls/design	Equipment Controls and Switches are Inadequate
Checklist layout	
Display/interface characteristics	Instrumentation and Normal Warning System Issues
Automation	
	Harness/straps inadequate
	Visibility Restrictions (not weather related)
	Use of Equipment Creates Unsafe Situation
	Personal Protective Equipment Usage
	Communication Equipment Inadequate

Selected Examples* from HFACS Level 1 Unsafe Supervision	Adapted Nanocode Statements
Preparation for Operations	
Failed to provide proper training	Training
Failed to provide professional guidance/oversight	Guidance
Failed to provide current publications/adequate technical data and/or procedures	
Failed to provide adequate rest period	
Lack of accountability	
Perceived lack of authority	
Failed to track qualifications	Maintenance of competence
Failed to track performance	Performance review
Failed to provide operational doctrine	Provision of Operational Doctrine
Over-tasked/untrained supervisor	
Loss of supervisory situational awareness	
	Provision of oversight
Supervision of Operations	
Poor crew pairing	Improper staffing
Failed to provide adequate brief time/supervision	Failed to provide adequate briefing
Risk outweighs benefits	
Failed to provide adequate opportunity for crew rest	Inadequate opportunity for rest
Excessive tasking/workload	

	Failed to provide correct data
	When using Operational Discretion
Managing Safety Issues	
Failed to correct inappropriate behaviour/identify risky behaviour	Failed to identify an 'at risk' firefighter
Failed to correct a safety hazard	
Failed to initiate corrective action	Failed to initiate corrective action
Failed to report unsafe tendencies	Failed to report unsafe tendencies
	Failed to correct inadequate guidance
Supervisory Violations	
Authorised unqualified crew for flight	Used unqualified personnel for task(s)
Failed to enforce rules and regulations	Failed to enforce rules and regulations
Violated procedures	
Authorised unnecessary hazard	Allowed presence of uneccesary hazard
Wilful disregard for authority by supervisors	
Fraudulent documentation	
Inadequate documentation	

Selected Examples* from HFACS Level 4 Organisational Influences	Adapted Nanocode Statements
Resource Management	
Human	
Selection	
Staffing	Doctrine for and adequacy of resourcing
Training	Structured training to establish and maintain skill, knowledge and competence
Background Checks	
	Assessment and selection of people for development as firefighters
	Assessment and selection of people for development as supervisors, managers and commanders
	Maintenance and recording of competence
Financial	
Excessive Cost Cutting	Use and allocation of funding
Lack of funding	Adequacy of funding
	Transparency of budget arrangements
Equipment/Facilities	
Poor equipment design	Arrangements for procurement
Purchase of unsuitable equipment	Trial and testing and assurance of suitability of new equipment

Failure to correct known design flaws	Withdrawal of unsafe equipment
	Provision, maintenance and response of appliances and equipment to meet operational demands
	Provision maintenance of PPE and RPE to ensure safety of operational personnel
Organisational Climate	
Structure	
Chain-of-command	Organisational structure
Communication	Communication
Accessibility/visibility of supervisor	
Delegation of authority	Delegation of authority
Formal accountability for actions	Accountability for decisions/actions
Policies	
Promotion	
Hiring, firing, retention	
Alcohol	
Accident investigations	Post event analysis that embraces the ethos of a Just Culture, free from fear and blame
Culture	
Norms and rules	Rules, guidelines and procedures for good governance
Organisational customs	
Values, beliefs, attitudes	Core values and belief's
Organisational Processes	
Operations	
Operational tempo	Operational tempo
Incentives	Performance measurement/appraisal/development
Quotas	Clear priorities
Time pressure	Performance Pressures
Schedules	Rota systems
Procedures	
Performance standards	Documentation - reviewed/developed/published
Clearly defined objectives	Clearly Defined Standards and Objectives
Procedures/instructions about procedures	Detailed guidance to deal with the range of operational incidents likely to attend
Oversight	
Established safety programmes/ risk management programmes	Risk Management

Management monitoring and checking of resources, climate, and processes to ensure a safe work environment	Safety Management
	Adequacy of Integrated Risk Management Planning Obtaining and providing operational risk information

Appendix 6

Simple guidance included with the excel workbook provided to participants for coding responses to both Study 2 case studies.

Human Factors Analysis and Classification Workbook

1. It's important that you use the case study document as the ONLY source of information for this exercise.

2. This spreadsheet is the workbook you'll use to record your responses to the case study exercise.

3. The tabs at the bottom of this page will take you to the various levels of HFACS you have read about in the accompanying guidance document.

4. Select the tab for those HFACS levels you believe are present in the case under scrutiny.

5. Consider the main category from those you can see and select the one that represents the error type you have identified as a contributory factor.

6. Now consider the relevant sub category and place an ✓ in the column that most applies to your selection of this sub category.

7. If you think a different category should be used enter it in the spare row marked with the '?' for the sub category

8. Finally, having made your selection, very briefly explain your rational for your choice, eg:
"*B1.2 Due to room temperature*".

Appendix 7

Results of coder moderation where, excluding Organisational Influences, nanocodes applied to the first three levels of failure of CS1 were modified and applied to the first three levels of failure of CS2.

CASE STUDY 1*	CASE STUDY 2**
Errors	
Skill Based Errors	
Incorrect use of equipment	Didn't use the equipment in the correct way
Poor technique	Adopted a poor technique during the task(s)
Omitted part of procedure	Left out part of the chosen procedure
Failed to prioritise attention	Didn't prioritise the task(s)
Distraction	Became distracted or interrupted
	Timing - too fast/slow
	Applied part of the chosen procedure out of sequence
	Didn't communicate safety critical information
	Didn't communicate unexpected developments
	Didn't recognise physical limitations to perform task
Decision Errors	
Adopted incorrect procedure	Adopted an inappropriate procedure for the task(s)
Inadequate risk assessment	Inadequate risk assessment - Didn't take action to reduce personal and team exposure to risk
Exceeded ability	Didn't recognise personal limitations in knowledge to carry out task(s)
Inappropriate action	On the available information, the right choice of action turned out to be unsuitable
Unsuitable choice of action	Chosen action was not suitable from the start
	Wasn't able to fully understand the situation
	Lapse of memory for some/part of the procedure
Perceptual Errors	
Visual impairment/illusion	Couldn't see hazard(s) well enough to understand it
Spatial disorientation	Didn't fully understand size, shape of location
Misjudged distance/angle/speed/size	Misjudged distance/time
	Didn't use all the available information and underestimated the situation
	Influenced by giving too much importance to some information

	Didn't ensure the necessary information to perform safely
	Failed to ensure vigilance for personal and team safety and react safely to unexpected hazards
Violations	
Routine Violations	
Failed to properly prepare for the task(s)	Didn't properly prepare for the task
Adoption of unauthorised procedure	Habitually steps outside the standard operating procedure for the particular task(s)
Violated training/guidance note	
Failed to adhere to equipment use/specification	
Failed to adhere to standard operating procedures	Used a 'local' version of the procedure to achieve the task(s)
Over aggressive use of equipment	Overaggressive - Doesn't routinely use the equipment in the way it was intended/designed
Not competent for the task(s)	Not actually competent to perform the procedure properly
Exceptional Violation	
Intentionally exceeded the guidance of the standard operating procedure	Stepped outside of the standard operating procedure because of the specific circumstances
Intentionally exceeded the limits of the equipment	Intentionally adapted the equipment being used because of the specific circumstances

CASE STUDY 1*	CASE STUDY 2**
Individual Factors	
Adverse Mental States	
Loss of situational awareness	
Complacency	Complacency – not taking due regard of the gravity of the situation
Finish the job it is	Perceived haste/pressure to achieve the task, get the job done (other than emotional state)
Mental fatigue (disorientation)	
Channelised attention (tunnel view)	Affected by tunnel vision – focus on job in hand not surrounding hazards
Distraction	Inattention/distraction due to mind wandering/failure to concentrate
Haste	Haste – adopted unnecessary urgency in task activity
Misplaced Motivation	
Task saturation	Task overload – trying to do too many things simultaneously
	Emotional state due to task demands - persons reported/trapped - involvement of children
	Emotional state due to scene - number/condition of victims
Physical Ability	
Medical Illness	Illness whilst performing task(s)
Fatigue - Overworked	Fatigue arising from task activity (overworked)
Impaired physiological state (drugs or alcohol induced)	
Fatigue - Heat	Fatigue arising from heat exposure arising from task activities
	Fatigue arising from heat exposure (climate/hydration)
Visual limitation	Visual limitations - corrected vision
Inadequate reaction time	Slow reaction to circumstances - decision inertia
Incompatible physical capability	Not physically able to perform task
Incompatible intelligence/aptitude	Not adequately competent to perform task
	Inadequately experienced to deal with task/circumstances
Team Factors	
Crew Resource Management	

Inadequate briefing/tasking	Ambiguous/inadequate crew task briefing
Communication/Coordination	
Misinterpretation of Communication	Misunderstanding/misinterpretation in communication (liveware) not resolved
Failure of Leadership	Inefficient/inadequate command and control (Incident Command System)
Failed to use all available resources	Insufficient use of available resources
Providing back - up	Insufficient resources
	Inadequate arrangements for turnover/rotation of personnel
	Inadequate arrangements for resting personnel
	Lack of team ethos
	Inadequate supervision of task activity
Personal Readiness	
Inadequate resting	Did not work sensibly and responsibly within the command and control arrangements of the Incident Commander
Self-medicating	Unfit to perform - self medicating using pharmaceutical drugs and medicines incorrectly
Sub-standard Physical Condition	Unfit to perform due to physical condition (strain/sprain/untreated illness)
Affected by substance or hangover	Unfit to perform due to alcohol/substance abuse
	Unfit to perform duties due to tiredness/fatigue (work life balance)
	Limited proficiency/experience
	Failure to ensure competence to perform allocated task
Environmental Factors	
Physical Environment	
Weather Conditions (wind, snow, rain etc)	Effect of weather-high wind-heavy snow/rain
Ground Conditions	
Light Intensity	Light intensity (dazzling)
Heat/Cold Stress influence on performance	Performance Affected by heat/cold stress
Impeded movement due to obstacle/confined space	Impeded movement due to obstacle/confined space
Climate (temperature)	Climate - ambient temperature
Obscured Vision (other than smoke, such as fog, snow rain)	Obscured vision due to snow/rain
Noise Interference	Influence of noise - volume/intensity
Darkness	Darkness - inadequate lighting
Smoke	Vision impaired due to smoke conditions
	Physical demand due to sloping/uneven ground conditions
	Physical demand due to debris covered ground conditions
	Physical demand of slippery ground conditions

Technological Environment	
Equipment Controls and Switches are Inadequate	Adequacy/suitability of equipment controls/switches
Instrumentation and Normal Warning System Issues	Operation of distress warning systems/alarms/alerts
Harness/straps inadequate	Security and performance of harnesses/webbing and their safety devices
Visibility Restrictions (not weather related)	Restrictions to visibility caused by the use of equipment
Use of Equipment Creates Unsafe Situation	Adequacy of chosen equipment leading to unsafe conditions
Personal Protective Equipment Usage	Performance and use of Personal/Respiratory Protective Equipment
Communication Equipment Inadequate	Performance of communications equipment (hardware)

CASE STUDY 1*	CASE STUDY 2**
Preparation for Operations	
Training	Inadequate provision for training and knowledge acquisition
Guidance	Inadequate provision of guidance and standards of performance and behaviour
Maintenance of competence	Ineffective oversight in ensuring maintenance of competence
Performance review	Inadequate scrutiny and assessment of workplace performance accompanied by review and feedback with view to improvement.
Provision of Operational Doctrine	Not an effective safety doctrine based on Firefighters maxim found in National Operational Guidance
Provision of oversight	
Supervision of Operations	
Improper staffing	Improper staffing
Failed to provide adequate briefing	Insufficient briefing and oversight during task activities
Inadequate opportunity for rest	Inadequate arrangements for welfare (rest/refreshments/removal)
Failed to provide correct data	Ineffective identification of goals
When using Operational Discretion	
	Inadequate/insufficient resourcing for meeting task demands
	Insufficient shared/distributed situation awareness
	Inadequate consideration of alternative task solutions
Managing Safety Issues	

Failed to identify an 'at risk' firefighter	Failed to Identify an underperforming or 'At-risk' Firefighter
Failed to initiate corrective action	Failed to initiate corrective action
Failed to report unsafe tendencies	Failed to report unsafe behaviour
Failed to correct inadequate guidance	Failed to correct inadequate guidance
Supervisory Violations	
Used unqualified personnel for task(s)	Failed to ensure personnel were competent to carry out task(s)
Failed to enforce rules and regulations	
Allowed presence of uneccesary hazard	Failed to ensure safe systems of work
	Failed to ensure personnel observe Safe Person principles

** Shading indicates where there was no corresponding nanocode statement used in Case Study 1.*
*** Shading indicates the corresponding nanocode statement was not adopted for Case Study 2.*

Appendix 8

Study 1 data capture workbook requesting 25 items of data in five sub-sets.

Fire and Rescue Service:	
1. Injured Party (IP) Profile	
1.1 FRS Record/ID Number Should it be the case that a particular injury is of interest, subject to informed consent and non-disclosure/confidentiality this information will only be used to identify individual cases for further inquiry.	
1.2 Gender M/F	
1.3 Age (D.O.B.) This will be used to compare against contemporary psychological theory that certain age groups are more 'risky' than others.	
1.4 Date of enrolment In conjunction with the previous data, this will be used to compare with contemporary theory that experience, albeit measured by length of service, could be a factor associated in operational injury.	
1.5 Duty System Whole Time or Retained (part-time) As you would record on the annual FRS return HS1-2	
1.6 Role Map Enter role map at time of injury and indicate with an asterisk if the IP was 'in development' eg CM*	
1.7 Injury History This will be used to identify if the IP is more or less likely to be injured. If this information is easy to access indicate by using a number otherwise enter Y/N.	
2. Temporal Profile	
2.1 Date of Injury	
2.2 Time of Injury	
2.3 Shift/duty being worked at the time Indicate Day/Night/Other. Identify using start time and end time eg 08:00 – 20:00. In the case of retained if at all possible indicate time of cover in the same way.	
2.4 Rotation This information will be used to explore a link with tiredness and/or fatigue. In the case of W/T this will identify when in the duty cycle or rota the injury occurred. Was it the first day shift or second night shift etc. eg first day shift D1 or second night shift N2. In the case of on call, retained or FDS duty if it is not too difficult to identify, indicate with Y/N if the IP attended an incident in the 24 hour period immediately preceding the injury.	
3. Incident Profile	

3.1 Type Fire RTC Water Hazmat Animal SSC Exposure In the case of other Non-fire describe where possible using a single word. Alternatively enter IRS Code.	
3.2 Surface Conditions This relates to surface conditions at the time of injury. Enter one of the following: Wet Dry Snow Ice In water	
3.3 Regardless of surface conditions if the ground was: Flat Sloping Steep Overgrown Uneven	
3.4 Weather Conditions at time and place of injury: Rain Snow Fog High Wind Hot/cold	
3.5 Visibility (Light/Dark) If artificial lighting was in use please indicate if it was: a) Normal street lighting; b) Torchlight; or c) FRS scene lighting; d) dark conditions; e) light; f) indoors.	
4. Injury Activity Profile	
Some of the following two data sets will probably be the more complex information for you to obtain, much of it will not be available until a more narrative explanation of the circumstances is known. It may help to cut and paste the information provided.	
4.1 Responding This relates to injury sustained from the time of call and before 'booking in' attendance at the incident (X in box).	
4.2 In attendance Injuries sustained at any time whilst in attendance at an incident before that described in 4.4 below (X in box).	
4.3 Critical This is to indicate if the IP was actively involved in direct contact with a risk assessed high hazard task where benefit outweighed risk of injury (Y/N). This means 'critical activity' relates to those circumstances where the risk-v-benefit balance required the IP to encounter a high risk but high benefit situation, one that includes the need for the IP to 'stay sharp', to be constantly doing their own Risk Assessment during a high risk task activity.	
4.4 Post Injuries sustained when hazards and risks have receded or are under control and most activities are biased to damping down, turning over, winding down, make-up and leaving an incident including the return journey to a turn out location.	
4.5 Severity Indicate using 1 for no time loss injuries, 2 for recordable injuries resulting in an absence of less than 7 days; and 3 for RIDDOR reportable injuries.	
5. Error Profile	
5.1 Litigation It may well be the case that you will be able to indicate if there is likely to be a subsequent litigation arising from this case which is the first and most important thing to indicate. **Y/N** or **U**nknown	
5.2 Level of Investigation Indicate if due to the nature/severity of the injury the investigation was completed at:	

1 = the supervisory level; or **2** = managerial level; or **3** = a more advanced level; or **4** = External Consultant	
5.3 Investigation Model Used This is about the technique, system or process your FRS uses to investigate accidents e.g.: Events and Causal Factors Analysis (ECFA); Combined Accident Analysis Method (CALM); Integrated Safety Investigation Method (ISIM); 'Fred Bloggs' error model; etc	

5.4 Active Error Descriptor

What follows is really quite subjective and is taken from the research and work of a number of academics. You will be familiar with the 'Swiss Cheese' model (SCM) which is about organisational resilience and 'defence in depth' which is another expression you will be familiar with. I have tried to guide you as best as I can using source text but if you have any difficulty with this particular profile data then please e-mail or phone me using my contact details below. What will become clear is that until an investigation is concluded and you are able to analyse the findings you will be unable to provide this information. It is however important to the research project that you use the information provided in your injury reports to make the most appropriate selections.

The reason this dataset focuses on the active errors of the individual is best explained by academics involved in their development:

"…all errors involve some kind of deviation. In the case of slips, lapses, trips and fumbles, actions deviate from the current intention. In the case of mistakes, however, the departure is from some adequate path towards the desired goal….Violations are deviations from safe operating procedures, standards or rules"

Managing the Risks of Organizational Accidents
James Reason (1997 9th Ed:71-72)

"By definition errors occur within the rules and regulations espoused by an organisation. In contrast, violations represent a wilful disregard for the rules and regulations…"

An Aviation Approach to Aviation Accident Analysis
The Human Error Analysis and Classification System
Weigmann & Shappell (2003:55)

Despite our best intentions the SCM demonstrates how errors in the system of an organisation can create a flow path that allows a brief window of opportunity for circumstances to combine and an accident to occur. These system weaknesses are, more often than not, only revealed by the actions that result in an accident. This is the 'active error' of the SCM and it is these immediate circumstances that this research focuses on. Reasons' principles have been developed into a Human Factors Analysis and Classification System (HFACS) which some of you may also be aware of but have no knowledge or experience in using. At this stage of the project this is not too important. There are four layers to HFACS that reflect the system of the SCM: organisational factors, unsafe supervision, pre-conditions of unsafe acts, and the unsafe act itself. However, at this stage of the research using your knowledge and experience I would like you to attempt to classify the unsafe act that resulted in this injury using the guide statements below. Making one selection from the 5 boxes below, place an **X** in what you consider to be the single most appropriate box:

1 Decision	

Often referred to as “honest mistakes” decision errors represent intentional behaviour that proceeds as planned but the plan itself is inadequate or inappropriate for the situation. Well intended actions without the appropriate knowledge or simply arising from a poor choice. These can be procedural or rule based where error occurs when the situation is not recognised, misdiagnosed or the wrong procedure is applied. They can involve a poor choice when presented with an option. Or they can occur when the situation is not well understood and formal response options are not available, where the invention of a novel solution is required. ***(As the research project develops you will be able to help align this to Operational Discretion).***

2 Skill Based	

Skill based behaviour occurs without conscious thought. It develops with knowledge of the practical application of taught and learned skills. As a result these skill based actions can be particularly vulnerable to failures of attention and/or memory. They are the simple attention failures of highly automatized behaviour. A typical example would be missing a turn at a familiar road junction or missing an appliance cab step.

3 Perception	

This is about not making sense of the situation, having a perception that differs from reality because of the environment. Not understanding direction when vision is impaired, or where size, shape and dimensions are misjudged in the dark or when in smoke.
Fortunately violations occur much less frequently than the errors described above but can result in serious injury. Violations occur when the individual knew what should be done but chose not to comply.

4 Routine	

These tend to be habitual and in some way tolerated by ‘blind eye’ supervisors or managers. Such as allowing routine violation of driving in excess of the speed limit during non-emergency driving. Simply seen as ‘bending the rules’ they are allowed by the line of supervision or management where their ‘permissive’ origins may lie.

5 Exceptional	

These are ‘exceptional’ isolated departures from the rules. They are more often than not heinous but not considered exceptional because of their extreme nature; it is because they are not typical of the individual responsible for the ‘active error’. Typically, when asked, individuals are left without an explanation for exceptional violations. They are often conscious of the possible consequences of their actions.

Contact details:
E: b.gough_research@btinternet.com
M: 07830 315004

Appendix 9

Content of contact letter used to request FRS participation and help in contacting potential participants for Study 3.

Dear ?

Human Factors analysis of Firefighter injury sustained during emergency response operations: Implications for error management and injury reduction in English Fire and Rescue Services.

You may recall that I recently wrote to you to record my appreciation for <SME Name> participation and support with the first Phase of the Firefighter Injury research project. The Phase 1 study involved analysing the data provided by all the participating FRSs to determine significant relationships and compare them with contemporary research into accident causation, judgement and decision making.

You also agreed to participate in the Phase 2 study which set out to triangulate aspects of Phase 1 and further explore the extent to which the FRS is or could be capturing, analysing and reporting the influence of human factors in the causation of injury at operational incidents. Phase 2 also examines how human factors data could be used as a predictive tool to inform the authors of operational guidance, and those responsible for learning and development, of typical error types associated with the critical decisions of firefighters. The project is now entering the final Phase of research. Phase 3 involves interviewing firefighters injured during a critical decision episode in order to establish what influence, if any, Human Factors had on their judgement and decision making. There are 93 cases that meet the critical decision criteria <number> of which was provided by <Name> Fire and Rescue Service. In my letter dated 19 September 2016 I gave you my absolute assurance that I would first seek your agreement and permission to contact any of your staff, which is the purpose of this letter.

However, the injured parties are known to me only as case numbers. It would be necessary for a member of your staff to identify the means by which their Participant Information and Consent to Participate (documents provided by me in a sealed envelope) can be provided to them. In this regard, as you are aware <SME Name> has already been very helpful in supporting the project. Subject to your participation, I would assume this mail contact would be made by internal (confidential) mail. In this way, the identity of injured parties will remain unknown to me until they personally make contact using the details I provide.

Their participation will be entirely anonymous and they will not be identified in any correspondence or publication either during or at the conclusion of the research. As with the previous two Phases of the project, the interviews will be conducted under the robust ethical requirements of Coventry University and the British Psychological Society. The handling of data will satisfy requirements for confidentiality and non-disclosure will be guaranteed to all participants as will their anonymity.

Before closing I would like to once again thank you for your participation in the Phase 1 data gathering study and Phase 2 triangulation study and hope for your continued support in exploring the potential to further reduce operational injury. If you should require any additional information I would be happy to meet with you or any of your officers/managers to discuss the detail of this final Phase of the project.

Yours sincerely,

Appendix 10

Content of initial Injured Party contact letter accompanying participant information forwarded by FRSs to potential participants of Study 3.

Dear ,

Please let me introduce myself, my name is Bill Gough and since retiring from the Fire Service I've been undertaking a PhD research project with Coventry University which is looking at the Human Factors that may in some way influence Firefighter Injury. The fundamental objective of this research is to identify the potential to further reduce the 1100 or so operational injuries that occur every year.

The information sheet contained in this envelope explains some of the important detail of the project.

The reason why you are receiving this information is because your Fire and Rescue Service reported that you were one of several firefighters who experienced an operational injury in the period April 2015 to March 2016.

Before you read any further it is important to emphasise that I am not aware of your identity.

Whilst I am aware of some of the circumstances of your injury, in accordance with the Data Protection Act, I have not been informed of anything that can be attributed to you as an identifiable individual or person other than demographic data such as gender, age and length of service.

You should have received this information in a sealed brown envelope with a reference number fixed across the seal. This number is the only means by which you are known to me. However, the only way I can make this initial contact is to ask your Fire and Rescue Service to forward the sealed envelope to you.

I hope you will read the information contained in the envelope with an open mind and I also hope you will agree to participate in this final phase of the research. I therefore, look forward to hearing from you soon. If on the other hand, after reading the information provided, you choose not to participate can I thank you for taking the time to consider the contents.

Yours sincerely,